Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

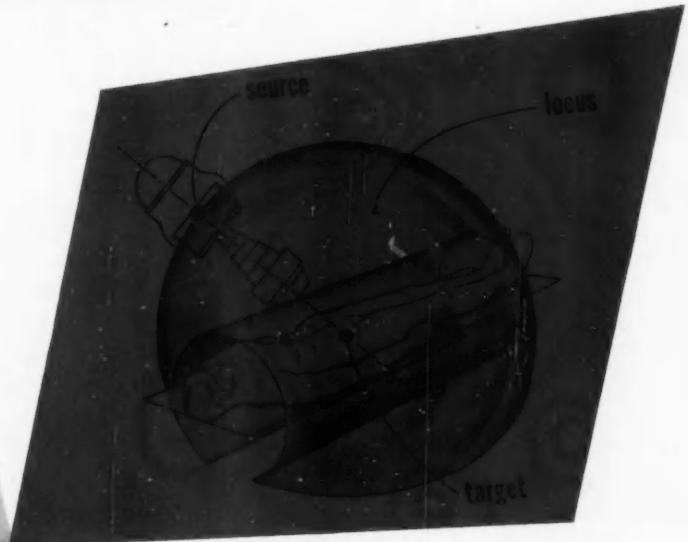
A McGRAW-HILL PUBLICATION

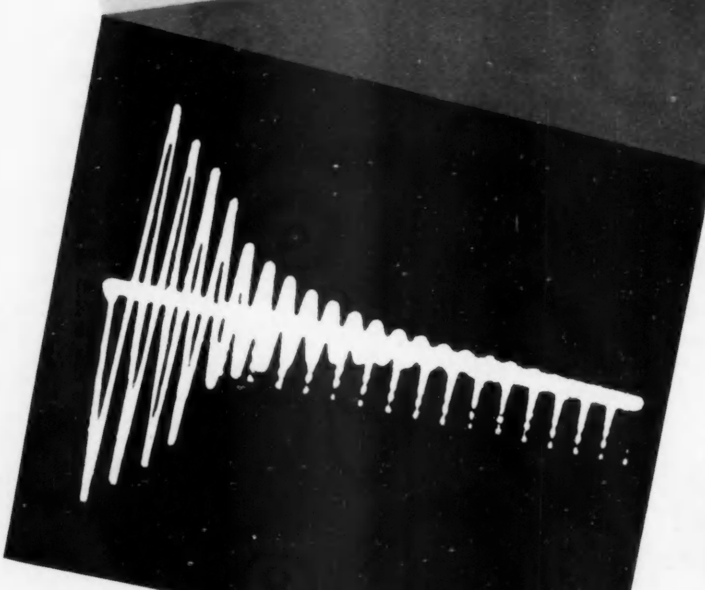
PRICE 50 CENTS

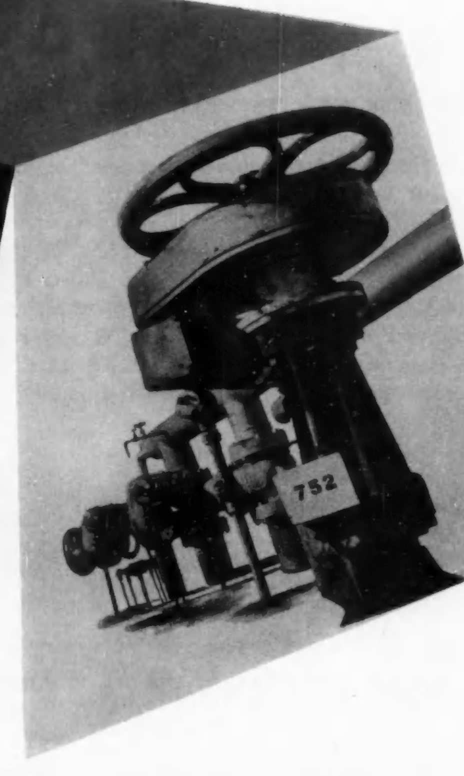
MAY 1955

IDEAS AT WORK

IN CANCER THERAPY
PIPELINE CONTROL
METER CALIBRATION







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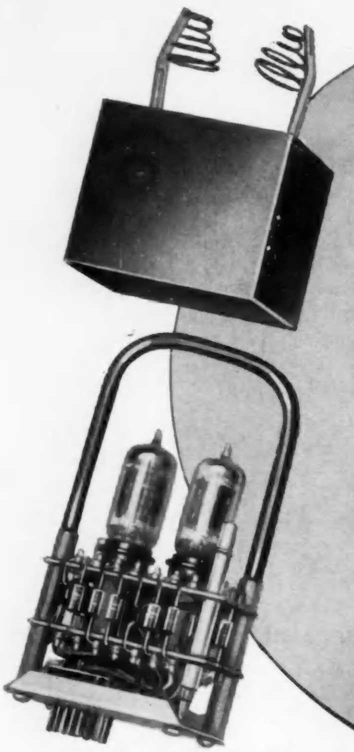
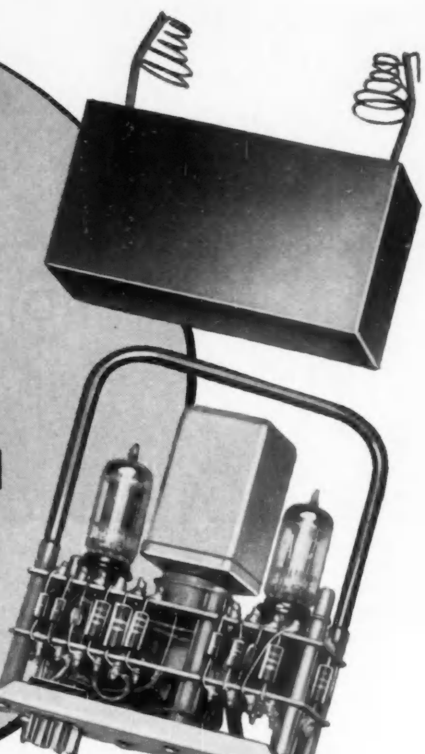


Plug-in Tone Transmitter
(Cover Removed)



Plug-in Tone Receiver
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When planning a system to operate apparatus at a remote location from a central master station, it is important not only that the equipment perform as required, but also that it be easy and economical to install and service. On the first count, Hammarlund Muti-Gate equipment assures fast-acting, fail-safe operation of a practically unlimited number of control functions over a single circuit. On the second count, it's a snap to install and maintain because of its new modular construction. And that means lower operating and maintenance costs.

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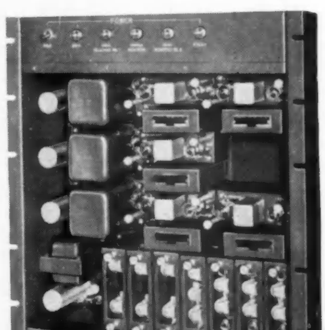


HAMMARLUND

EQUIPMENT FOR **COC**—CENTRALIZED OPERATIONS CONTROL

Control ENGINEERING

MAY 1955

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

PRINT ORDER THIS ISSUE 25,459

SHOPTALK

ALAS, GEORGE LEAVES

If you have enjoyed reading What's New, Pulse, and the magazine in general, why, thank George Boehm. This sprightly journalist-scientist manages the works, and somehow finds time to play tournament bridge. But alas, George leaves us to join "Scientific American." How we'll miss him.

Before departure, George (left) cast a last, nostalgic eye at Art Director Jack Gordon's cover design for this issue.

. . . BUT SLATER'S ON THE SCENE

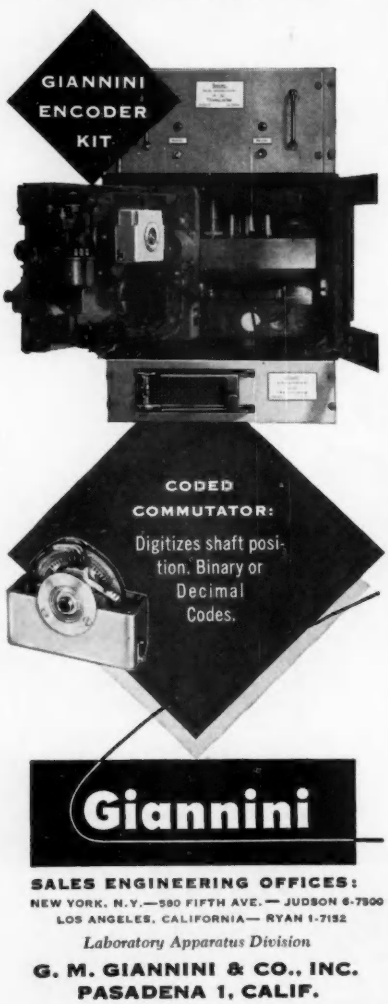
Luckily, George's verve was catching. As Business Editor, Lloyd Slater got more than a mild dose of it, so he's taking on the job of Managing Editor with this issue. If you're a maker or a user of control surely you met Lloyd when he rambled over the country applying Brown instruments or when he worked the midwest as field editor for "Food Engineering." So you know that he'll bring the same bustling energy and enthusiasm to this new job. We know it, too. That's why we picked him.

DON'T SEND HEN'S TEETH TO SHOWS

While covering the recent IRE conclave for our feature news story in this issue we paused at the employment notice board in the lobby of the Waldorf-Astoria to tack up our hopeful request for an editor. While searching for an open spot midst the densely packed slips we heard two venerables at the edge of the crowd. "Good engineers are as scarce as hen's teeth," one growled. "Get one and he floats off to a new job next week. Darned if I'll send the boys to look at this bulletin board next year." Incidentally, we're still looking for that editor. Know one?

EASTERN METEOR HITS WEST COAST

We rather doubt that west coasters will ever get over By Ledgerwood's recent one-month tour through their control industry. By marched on the coast armed with typewriter, soundscriber, MS paper, and two nylon shirts. He worked during breakfast, lunch, and dinner, visited two plants daily, and edited manuscripts each evening. You'll see the results for months.



FEEDBACK

'Tain't . . .

To the Editor—

In your January issue the article "How to Operate a Two-Phase Motor from a Single-Phase Source" brings out two points which I question.

1. It is stated that the required external impedance generally has a resistive component which may be negative. I believe that the resistive component can always be made positive by the proper choice of a 90-deg phase lead or lag between the phase 2 voltage and the single-phase line in the original derivation of the required external impedance (Z).

2. The statement is also made, "In practice, the resistive component of the external impedance is neglected, and phase shifting is accomplished by a capacitive component only." This would be true only if the resistive component of the impedance of phase 2 is approximately the same magnitude as the reactive component of the impedance of phase 2. For motors in which the reactive component is large in comparison to the resistive component, the net voltage across phase 2 would be much greater than the rated voltage if no series resistor is used. This would result in saturation of the iron and over-heating of the phase 2 winding.

V. Tatosian
Vickers Electric Div.
St. Louis, Mo.

Yes 'tis

To the Editor—

1. It is not possible to choose phase lead or phase lag to obtain a resistive component which is positive. This is apparent from the equation for the impedance Z given in the paper. The ratio $\frac{E_1}{E_2}$ can be positive or negative depending upon phase lead or lag.

continued on page 8

PROBLEM FORUM

Keep sending in your problems. Someone in this multidimensional field will tackle them through this column. Or if a problem is presented by many readers, we will publish a feature article treating the subject thoroughly. Our cash offer for challenging problems and outstanding solutions still stands. This month's prize-winning problem—Number 4

To the Editor—

In automatic control of the frequency and voltage of large ac and dc machines the conventional RC stabilizing networks are very bulky. A common stabilizing means in these cases is a "rate transformer." Its primary is in series with the field winding (in some cases it can connect in parallel), and its secondary feeds the control finding of a magnetic amplifier or a rotating amplifier (amplidyne). In the steady state, the secondary voltage is zero; during transients, the secondary voltage is very nearly proportional to the rate of change of the field current or field voltage.

This stabilizing transformer is an important part of the complete system, yet it cannot be purchased. It must be designed and fabricated for each specific problem. There is no published paper on a design method. Control Engineering will render valuable service if it publishes a procedure.

Name withheld

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Another cost-reducing

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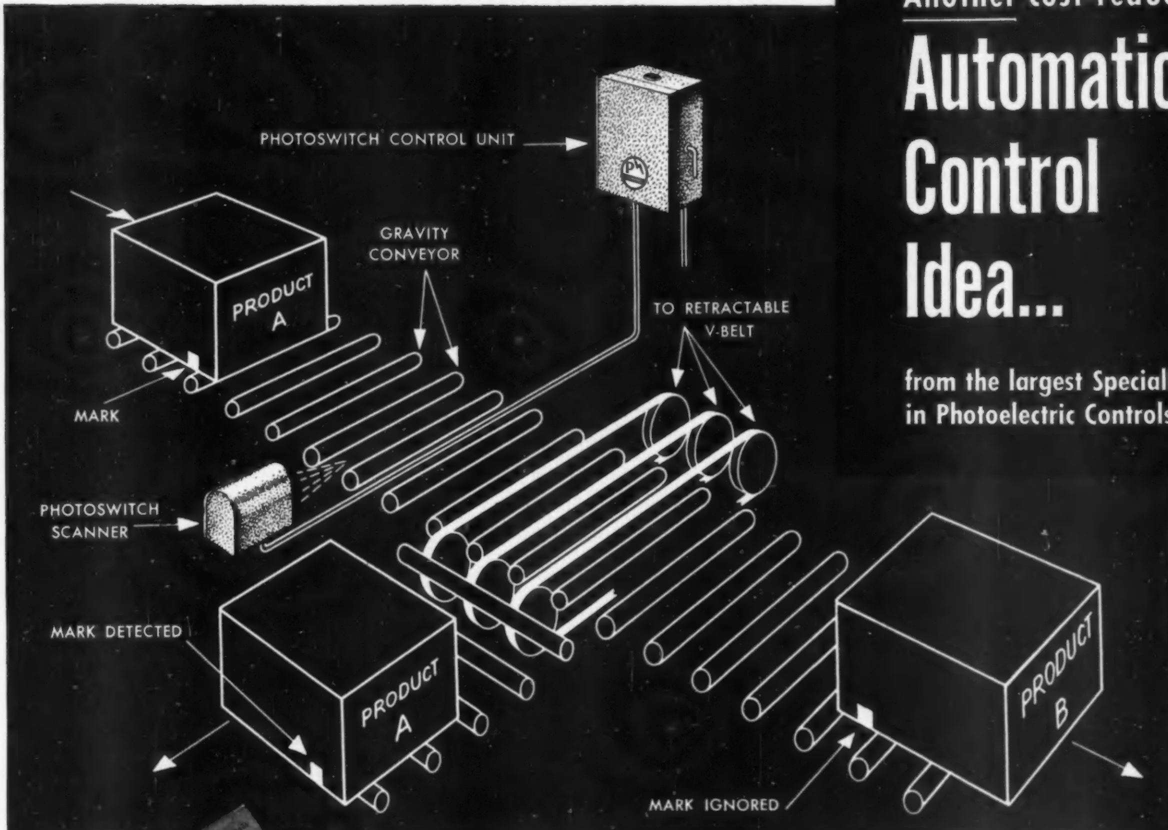

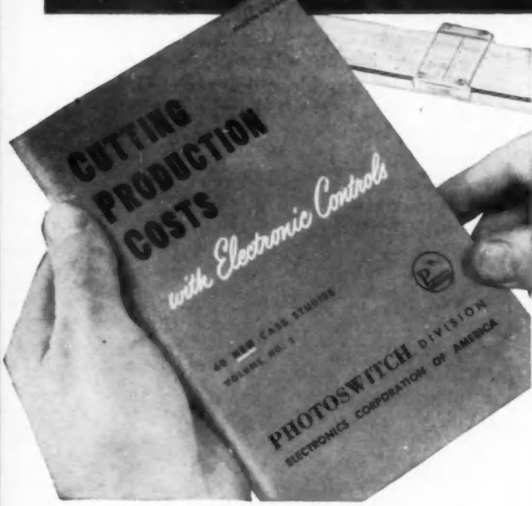

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This control design is typical of thousands of successful Photoswitch Systems for Automatic Electronic Control of Machinery and Processes. In Photoswitch's wide variety of "ready-to-use" photoelectric controls, liquid level controls and electronic timers, you will find controls that meet your requirements exactly. For the solution of your control problems, see your Photoswitch representative.

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FEEDBACK

Nevertheless, the resistive component for those cases in which R_2 exceeds $\frac{E_1}{E_2} \bullet X_2$ will remain negative. A resistive component with positive value can be sometimes obtained if the voltages E_1 and E_2 are not equal. Thus, for the case where $E_1 = 24$ v and $E_2 = 120$ v and $Z_2 = R_2$, operation from a single-phase 24-v source would require a resistive component equal to $(\frac{24}{120} - 1) \bullet R_2$, which is negative. If it is permissible to operate this motor from a 120-v source (which means interchanging E_1 by E_2) the resistive component becomes $(\frac{120}{24} - 1) \bullet R_2$, which is positive. This, of course, is not always possible.

2. Mr. Tatosian's apprehension concerning the omission of the resistive component for equivalent single-phase operation is well founded. This can be illustrated for the case of a 400-cycle, 115-v, 2-phase servo motor commonly designated by the Bureau of Ordnance, Navy Dept., as MK 7. This motor has a control winding with $R_2 = 490$ ohms and $X_2 = 890$ ohms. The resistive component of the impedance to obtain equivalent operation from a single-phase source should be 400 ohms. If this resistance is omitted and only the capacitive component used, the voltage appearing across the control winding will be 169 v, which may not only result in damage to the motor but also cause the motor to perform in a way which is not equivalent to its performance from a 2-phase source. If the article gave the impression that the resistance component can be omitted indiscriminately, Mr. Tatosian's comments are in order and must be heeded if proper equivalent operation is to be obtained.

K. Burian
G-M Laboratories, Inc.
Chicago, Ill.

Errata

To the Editor—

In the article "A Broad Look at Analog Computers" [CONTROL ENGINEERING, Vol. 2, No. 2] I believe that several equations in Fig. 2, page 56, are in error. For the "Multiplication-Division" device the mathematics should read:

$$\text{If } c = 1,\ a \times d = b$$

$$\text{If } d = 1,\ \frac{a}{b} = c$$

For the "Differentiation-Integration"

device the second equation should read:

$$\frac{d\theta_o}{dt} = a\,\frac{d\theta_i}{dt}$$

These comments are not directed as criticism of your fine journal but as constructive suggestions.

Charles H. Draper
Diamond Alkali Co.
Cleveland, Ohio

The sharp-eyed Mr. Draper is correct. Make the indicated changes in your copies.—Ed.

A Grave Answer

To the Editor—

Your recent letter . . . asked for more information on the Martin anti-gravity research program referred to in an employment ad. George S. Trimble, Martin Vice President of Advanced Design, . . . tells us:

"At the present time, anti-gravity research involves fundamental study of Field Theory as expounded by Einstein and others. We will attempt to determine, first theoretically and later experimentally, the basic laws of nature concerning gravity in the belief that an understanding of it will lead ultimately to its control by man."

Clayton J. Knight, Jr.
Glenn L. Martin Co.
Baltimore 3, Md.

After reading this provocative reply, an associate doodled, thus, on a tablecloth:—Ed.

"Are you the guy who poo-poohed our anti-gravitation theory?"

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A
CONTROL
PERSONALITY

DR. NICOLAI MINORSKY
pioneered control theory

Dr. Nicolai Minorsky has never received the general recognition due him for laying the theoretical foundations of high-order derivative control actions. Thirty-seven years ago, long before control engineering became a defined branch of applied science, he recognized the need of these actions and formulated rational expressions of them. He verified their benefits by applying them to automatic steering apparatus for the *U. S. S. New Mexico* in 1923.

Dr. Minorsky regards his activity in the early days of control engineering "in a rather melancholy way, in the sense that an idea that comes before the situation is ripe remains only an idea. In my case, this was a quarter of a century ago, so I am still alive to witness the realization."

His navigation instrument led him to develop control theory

Dr. Minorsky was born Sept. 24, 1885, in Korcheva, Russia, and got his Doctor of Engineering degree at the Imperial Polytechnic School at Petrograd. During World War I he served as Electrical Officer of *H. I. M.S. Sevastopol.* After he was displaced by the Bolshevik revolution from war work with the Russian Naval Attache in London and with the Inter-Allied Committee for (War) Inventions, he came to the United States to develop one of his inventions—the constrained gyro. In later years this instrument, the "gyro turn-indicator," was used extensively in aircraft. Even more significant, it started him developing an actual control system responsive to high-order time derivatives of departure.

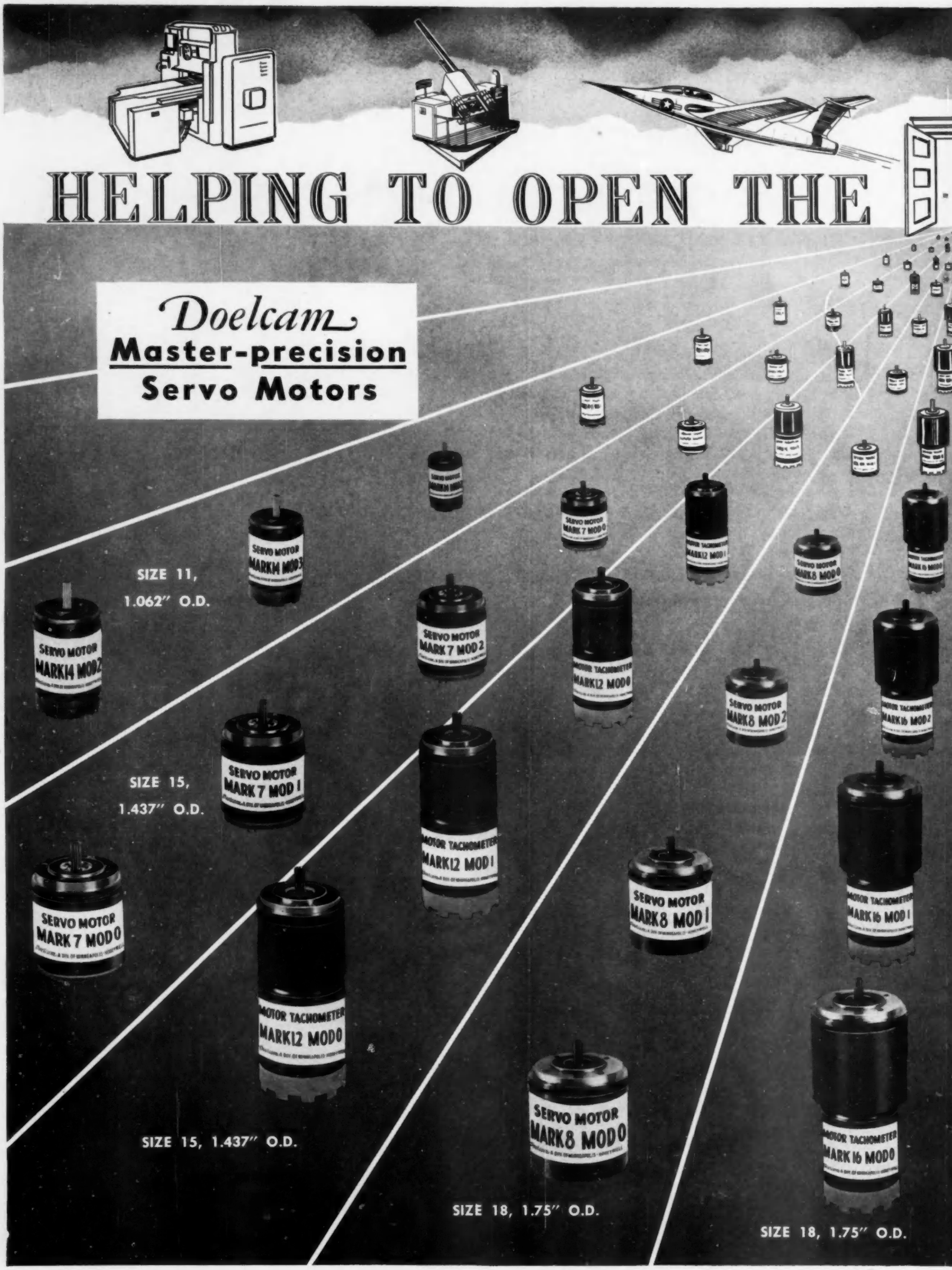
Three documents tell this development story:

U.S. Patent 1,436,280, "Automatic Steering Device," stakes the claims.

"Directional Stability of Automatically Steered Bodies," in the "Journal of American Society of Naval Engineers," 1922, presents the mathematical analysis, of which the *New Mexico* trials were proof. The last few pages of this article develop the differential equations of a general fourth-order motion-control system, including second-order derivative control action. Stability is examined by the Hurwitz criteria. As Albert F. Sperry, president of Panellit, Inc., writes, "For fifteen years after this, we were digging out this information. It is really quite a travesty that this generalized work was lost in the literature."

"Automatic Steering Tests," "Journal of American Society of Naval Engineers," 1930, told in Dr. Minorsky's vernacular, is an excellent narrative. Any control engineer who has attempted dynamic analyses of control systems in operation will appreciate Dr. Minorsky's trials and tribulations during the steering tests. The *New Mexico* was a battle-division flagship leading an entire formation through maneuvers from Puget Sound to San Pedro. Because of the tactical evolutions of the formation, systematic dynamic studies of the steering gear were impossible. Only on the rare occasions when the ship fell out of formation was Dr. Minorsky's work-party able to snatch a minute or two to study and adjust the controls. However, they persevered. During the final tests off San Pedro, the ship steered automatically well within plus or minus ten minutes of course by continuous, smooth rudder action, in contrast to the discontinuous, rather severe action of the human helmsman.

Continued on page 134



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SERVO MOTOR
MARK 7 MOD 1
MOTOR TACHOMETER
MARK12 MOD 0
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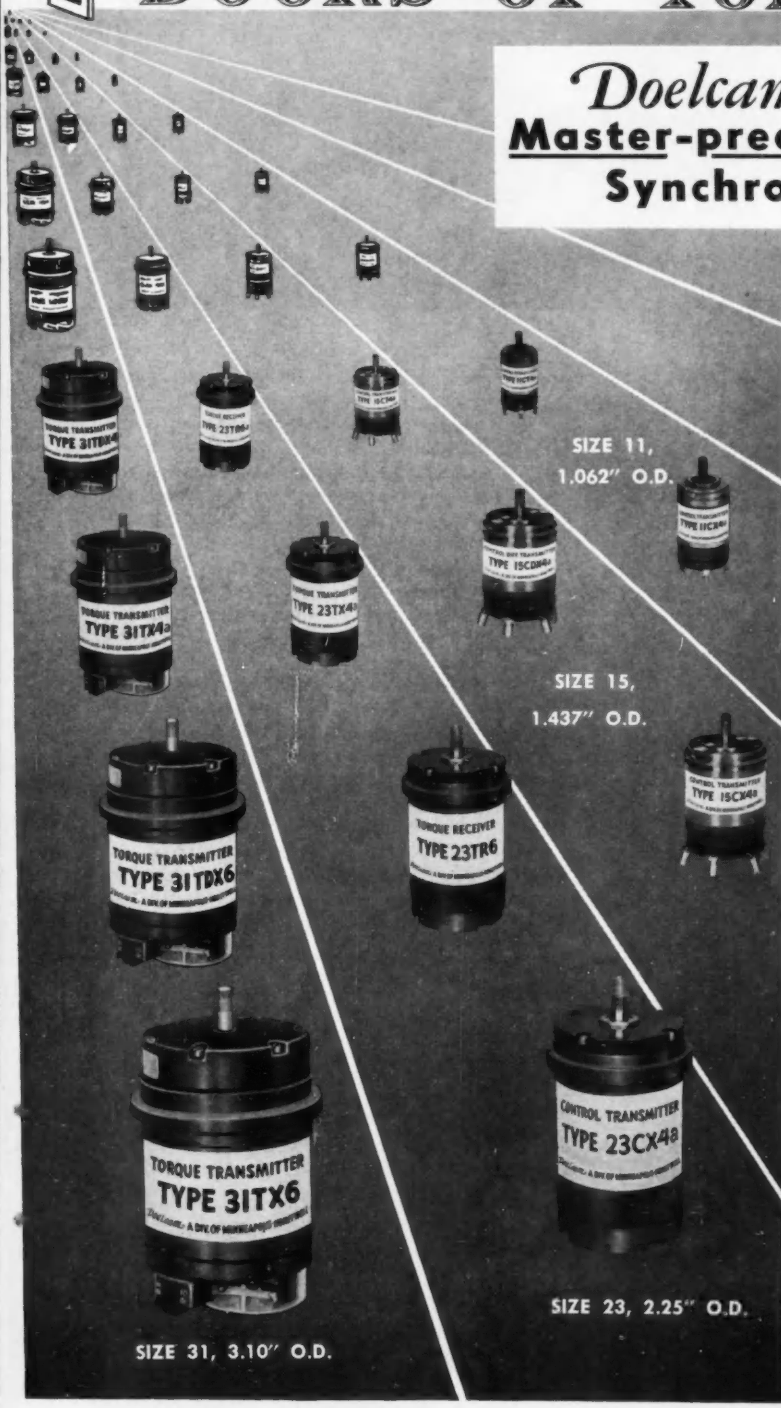
MARK8 MOD 0
MOTOR TACHOMETER
MARK 16 MOD 0

DOORS OF TOMORROW...



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Write for Bulletin S 34

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Write for Bulletin SM 34

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IN THE BOOTHS . . .

. . . they relaxed around comely informants or tensed over the controls of the "Radar Rocket."

40,000 Radio Engineers Map a Broad Future For Control

Spring came to New York City in 1955 with a deluge of rain and radio engineers. The blasé natives shrugged off the weather. But they may never get over its electronic accompaniment. Regular travelers on the Jerome Avenue subway line still mutter about it.

For this year's Institute of Radio Engineers four-day conclave was awesome. Over 40,000 electronics-enthusiasts converged on the city. They found the meeting spread between technical sessions in midtown Manhattan hotels and show exhibits ten miles north in a brownstone castle in the Bronx. The result was perpetual hegira on subway and bus, with local riders properly dazed by electronics esperanto. Many eager engineers made this round trip twice each day.

Under steel girders of the Kingsbridge armory they trudged over a mile and a half viewing wares in 895 booths. Another 100 booths in nearby Kingsbridge Palace carried the overflow displays. And downtown they packed into swank ballrooms at the Waldorf Astoria and Belmont Plaza to soak up 275 papers in 55 sessions.

Taken in one dose, it was the biggest technical shindig to hit New York since the World's Fair.

The armory displays reflected a broad new scope for the electronics art. This was no mere communica-

THEY CAST A SEARCHING EYE . . .

. . . to catch the design and application features in products which would help them in their jobs. Their big interest was in new circuits, more rugged components, better linkages, and simpler construction. They peered and squinted, and where they could, they fiddled.

. . . AND AT THE SESSIONS

. . . they settled back to absorb progress and occasionally sidled out to scan the job offer board.

tions show. Besides usual circuit hardware, the booths held servos, analog computers, counters, telemetering units, motor controls. The feverish rush to solid state devices also was evident. At least three dozen new semi-conductors and magnetic amplifiers were on view.

A decided control engineering bias was in the air. Naturally, the control virtues of transistorized circuits and magamps were played up. But the automatic control functions of most other electronic hardware were emphasized in displays and giveaway literature. Over 400 of the 704 exhibitors classified as control field vendors.

As usual, the working exhibits got the best rise. Walter Mittys in the crowd lined up for a dogfight session in Westinghouse's "Radar Rocket." Others grinned as Librascope's versatile X-Y plotter impishly dotted out shapely chorus girls on graph paper. More practical seekers crammed into International Electronic's inner sanctum to watch ultrasonic soldering.

Some of the developments captured attention by sheer promise. Industrial control people pondered over Du Mont's new optical scanner that counts the objects it sees. Computer engineers did a double take at Philco's streamlined circuits based on surface barrier transistors. Geophysical researchers pounced on Millivac Instruments' hushed amplifier—said to have less than one-half of one-millionth of a volt noise over a frequency band of 60 kc. Data-processing experts were fascinated with the new Hughes storage tube that reads out in printed words. Medical pulses quickened when showgoing doctors sighted Altec Lansing's thimble-sized microphone with great heart diagnosis potential.

Sessions Also Control Biased

Engineers found the downtown technical sessions equally rewarding. As had the hardware, they catered to every interest. Some of the topics in 55 special sessions: microwave theory; ultrasonics; telemetry and remote control; medical electronics; nuclear science; computers; information theory.

Once again, control field interests seemed to bias the proceedings. True, full recognition of electronics in this field came in a special session and panel. But unmistakable touches of control engineering flavored many of the other papers.

Take flight in space. The Waldorf's Grand Ballroom bulged when five experts held their symposium on telemetering and remote control of a space station. Cramped quarters were quickly forgotten as listeners coped

with instrument problems in a small ball whizzing around the earth 250 miles aloft. This was the MOUSE, or as its keen young originator Professor S. F. Singer delineated, Minimum Orbital Unmanned Satellite of the Earth. There was little doubt that MOUSE will be in the air in a few years and that control engineers will soon design loops that lap towards the moon.

REDSTONE'S STUHLINGER: Shaped like a cosmic butterfly.

A bigger, more commercial version of the MOUSE was described by informal, easygoing John Pierce of Bell Telephone Lab. This is to be a relay satellite which will yo-yo TV programs overseas. Eminently practical, Dr. Pierce fixed his 100 ft relay in an orbit 22,000 miles above Earth and set it up for 30 channel handling of an 8-digit binary pulse modulation system. Estimated cost: $35-million—just about as expensive as a good transatlantic cable laying job.

But the audience really rose off its seat when Redstone Arsenal's Dr. Ernest Stuhlinger modestly revealed his design for a ten-man space ship to Mars. With a matter-of-factness tinged by his soft German accent and years of pioneering the V-2, Stuhlinger declared his vehicle would look like a "cosmic butterfly" and run electrically. Some slides showed problems well within scope of today's engineer.

Prospects for engineering growth were just as bright in other, slightly more earthly sessions. The special panel on "Design of Machines to Simulate Behavior of the Human Brain" also drew a sell-out crowd. One panel expert, MIT's bearded Warren McCulloch, typified the unfettered intellect of neurologists searching the computer field for ideas. Another, A. G. Oettinger of Harvard's Computation Lab, made it clear that reciprocal knowledge is expected from computer people studying neurology. Conclusions? At this point it's a toss up as to who will benefit most from this cross-fertilization. But obviously work in neuro-analogous mechanisms and neuro-programming computers is going on at fever pitch.

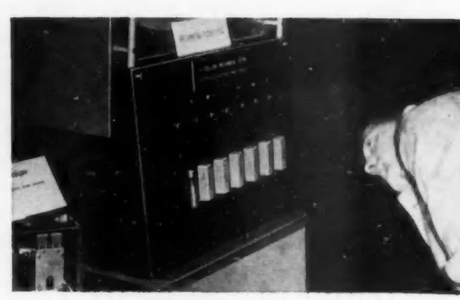
Similar cross-fertilization between fields appeared in the medical electronics symposium. Here the experts were physicians and feedback specialists. The progress they reported in new instruments to diagnose and treat disease was exciting. But the panel's dynamic Britton Chance made this sobering point: "Real progress in medical electronics will only come when the 'hybrid' with special training can be sure of a market for himself. He's got to be a biologically oriented systems engineer. The salary level has been too low to attract top engineers

NEUROLOGIST MOLDAVER: A transducer for the shankbone.

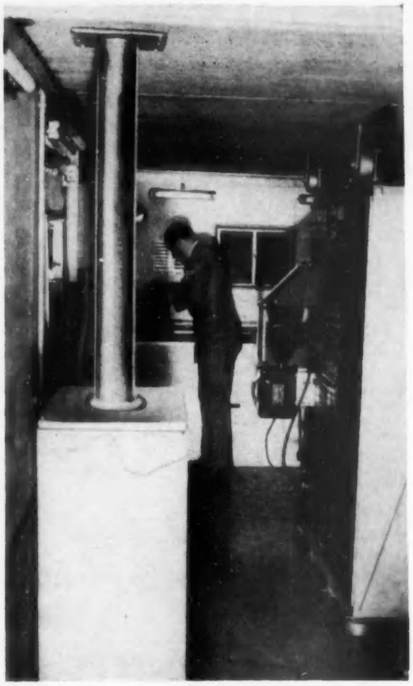
STANFORD RESEARCH'S LEE: Sometimes less control is cheaper.

Straightforward automatic control members of IRE got their licks in a special three-hour session during the first day of the meeting. An outstanding contribution was made by L. B. Wadel of Chance Vought Aircraft in a paper on the use of integrators as storage elements for the signals in sample data handling systems. In general, the session indicated that radio engineers are analyzing servos to achieve finer and finer levels of precision.

The zealous IRE interest in automatic control reached its peak in the Waldorf's sumptuous Starlight Roof on Tuesday evening, March 22. Close to 500 foresook nearby lures to hear Dr. Gordon Brown moderate a panel discussion of "Trends in Automatization of Procedure and Processes in Business and Industry." The speakers—an executive, engineer, editor, and sociologist—offered a broad-gauge view of this active subject.



LABS ON WHEELS
Five tons of measurement and control instrumentation are now touring the country in Consolidated Engineering Corp.'s sleek trailer. The vehicle has its own 25 kw generating plant. It plans 125 demonstrations along its 25,000-mile route.



Armour Research Foundation rivals Consolidated's show with a 28-ft van packed with data-analysis equipment. First assignment for this mobile laboratory equipment will be to evaluate a rock crushing machine in a Racine, Wis., quarry.

Big Marriage Slated in Control Field

With the imminent merger of Remington Rand and Sperry Gyroscope, one of the most important marriages in the computer control field will take place. Involved in the stock shuffle are 3¼ shares in the new company (so far unnamed) for each Sperry share and 2 shares for each RemRand share.

Control Conferences And Computer Clinic

The National Industrial Conference Board and the Stanford Research Institute have joined hands to sponsor a national symposium on "Electronics and Automatic Production," Aug. 22 and 23 in San Francisco. More than two dozen papers will range from assessing sociological developments that attend automatic production to down-to-earth product design.

Concentrating on engineering details, Purdue will sponsor a conference on systems engineering, July 25, 26, and 27. Directed by the school of electrical engineering, with the cooperation of midwest industries, the meeting will emphasize automatic control in industry. Sessions will be devoted to computers and simulators in control systems, recent advances and applications of network and information theory, and the relationship of certain properties of error-sensers to system design.

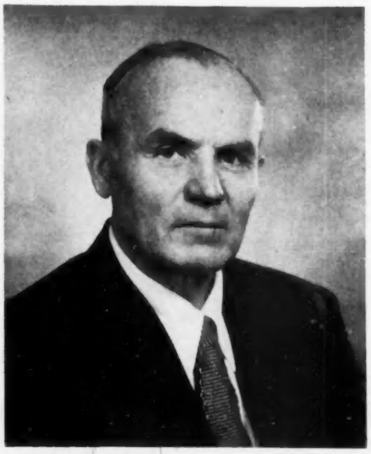
Completing the summer's interchange of ideas, the Instrument Society of America plans to add a computer clinic to its Sept. 12-16 show in Los Angeles. W. J. Conner, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., will be clinic chairman.

Important Moves by Key People

▶**Daniel G. Russ,** formerly senior projects engineer for Bendix Products Div., now is general manager of a new Aviation Div. of CDC Control Services, Inc.

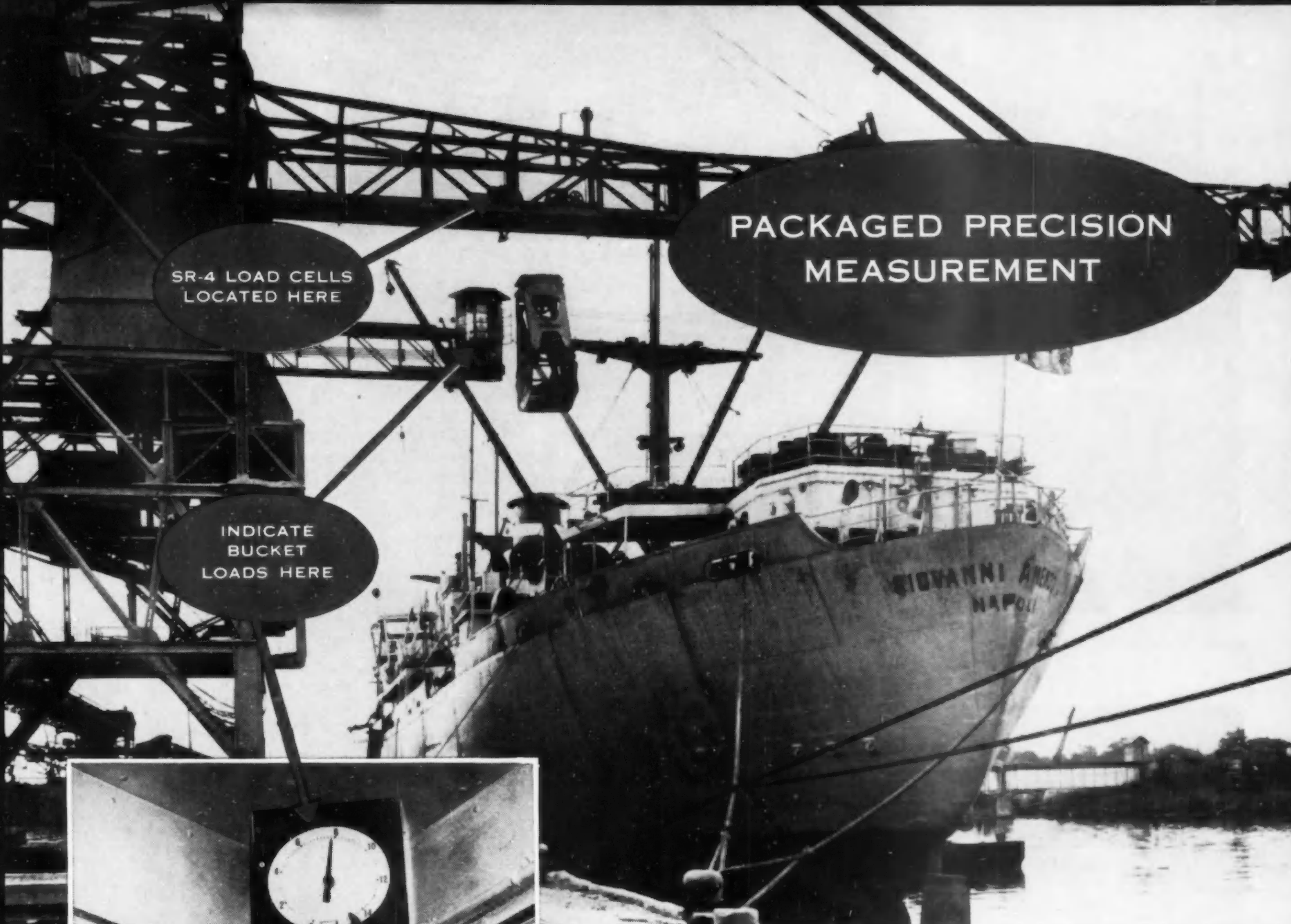
▶**James F. Gordon,** the new chief development engineer of Helipot Corp., formerly was chief engineer in the Berkeley Div. of Beckman Instruments, Inc. He also has been principal research engineer of Bendix Radio.

▶**William Wockenfuss,** who has been named assistant vice-president of engineering of Burroughs, Corp., will continue as vice-president of engineering of Control Instrument Co., a Burroughs subsidiary.



Poniatoff board chairman of Ampex . . .

. . . and Long succeeds him as president



Baldwin SR-4 System indicates and continuously totalizes ore loads in the crane cab (above). The operator has a continual check on the load being carried by the clamshell.

At Alabama State Docks this Heyl & Patterson crane . . .

unloads ore faster by using SR-4® automatic weighing system

Baldwin's "Packaged Precision Measurement" can cut your ore handling costs. That's been proved at the Alabama State Docks, Mobile, Alabama. There a Heyl & Patterson unloading crane is using Baldwin SR-4 load cells and recorder to weigh electrically clamshell buckets of ore.

This Baldwin SR-4 automatic weighing system benefits this user three ways:

1. **Faster handling:** The bucket does not have to be stopped to determine weight since its weight is being continuously measured by two 20,000 pound load cells in the sheave block. More ore can be handled by the unloading equipment each shift, reducing handling costs.
2. **Easy operation:** A large indicator dial in front of the operator tells him when to add the weight on the totalizing counter. The indicator totalized the weights measured by two distant SR-4 Load Cells and zeroes out all but net weight of ore.
3. **Low maintenance:** SR-4 Load Cells have no moving parts to wear out. They are sealed against air-borne dust They are giving accurate, dependable service.

Baldwin SR-4 Load Cells can solve your weighing and force-measuring problems. Write for our *new* Bulletin 4301. It's loaded with detailed information on typical applications and instrumentation for these unique devices. It tells you how to use them for local or remote indication, recording, signaling or process control. Use coupon today!

Department **3265**
Baldwin-Lima-Hamilton Corp.
Philadelphia 42, Pa.
(In Canada: Peacock Bros., Ltd., Montreal, Quebec)

☐ #4301 (SR-4 Load Cells and Loan Beams)
☐ #4304 (SR-4 Crane Scales)
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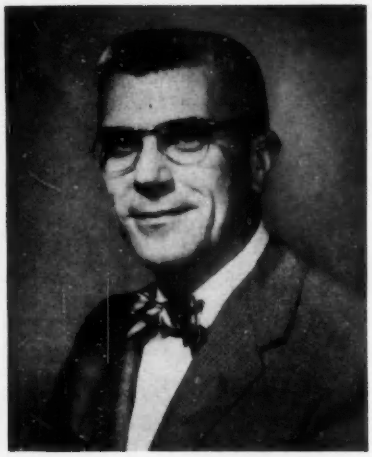
BALDWIN BLH LIMA-HAMILTON

Eddystone Division
BALDWIN-LIMA-HAMILTON



Olson division engineer of Motorola

▶ **Arnold Tustin** has been named to the chair of electrical engineering at Imperial College, London.

▶ **Roy H. Olson** will pilot the Industrial Products Dept. of the Communications Electronics Div. of Motorola, Inc., as director of engineering in that division. He joined Motorola in 1951 in the Phoenix Research Laboratory.

▶ **Harold R. Larsen,** vice-president of Servomechanisms, Inc., has been named general manager of the Eastern and Western Divs. He joined the company in 1938 and since 1952 has been manager of the Western Div.

▶ **Dunstan Graham** has been appointed section head of flight control systems in the instrument engineering group of Lear, Inc., in Grand Rapids. Most recently with Wright Air Development Center, Dayton, he also has been a research project engineer at Cornell Aeronautical Laboratory and aerodynamicist at Boeing Airplane Co.

Larsen moves up at Servomechanisms

COMPUTER ROUNDUP

Ford's Sad Celebration

On March 12, just a month before Ford Instrument Co. celebrated its 40th anniversary, its founder, Hannibal Choate Ford, died at his Kings Point, Long Island, estate. A fitting memorial was a company museum displaying Ford's most notable invention, the world's first naval gunfire computer (see cut). First tested by the U. S. Government in 1917, it later revolutionized war at sea. Among his other important contributions were the first automatic tracking bombsight, the first anti-aircraft computer and gun pointer, an automatic computing sight for airplane machineguns, and the gyroscope that he helped Elmer A. Sperry develop back in 1909.

Five years after the gyroscope project, Ford formed his own company, which is now a division of Sperry Gyroscope Co. Throughout his life he was a creative electrical engineer—an interest that was evident from the elec-

Continued on Page 22

This computer revolutionized war at sea

And this one, almost 40 years later, may accelerate a new supersonic air age

Graham heads Lear engineering unit

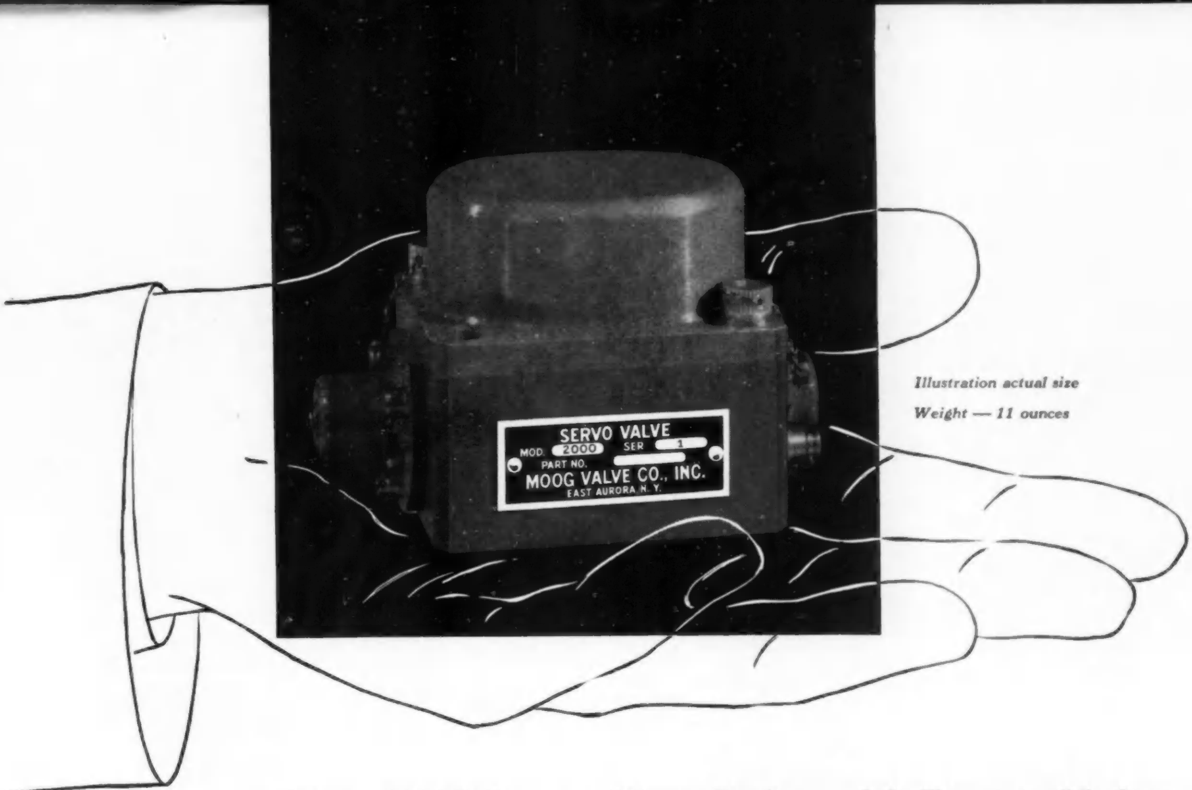
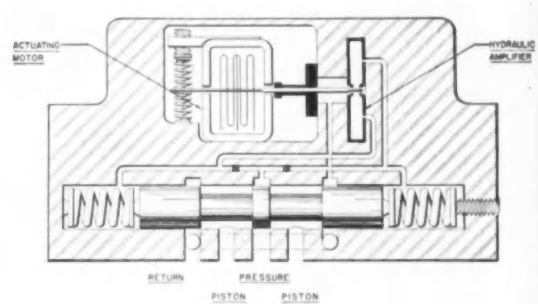


Illustration actual size

Weight — 11 ounces

From MOOG . . . a **Dry Solenoid Servo Valve**



For those electro-hydraulic servo systems which require valves of high dynamic performance, reliability, small size and low weight, Moog units have achieved recognition as the industry standard.

And now, for those systems in which the fluid contains entrained iron, Moog has developed the Model 2000 Servo Valve. These units feature a dry solenoid which eliminates the possibility of torque motor contamination due to magnetic particles. These valves comply with requirements of MIL-H-5440A and are smaller and lighter than other Moog units of the same flow capacity.

Moog Valves, including Model 2000, are proportional type, electrically actuated, hydraulic, four-way valves featuring high dynamic response, sensitivity, linearity, and reliability. Production models are designed to operate in hydraulic systems of from 1000 to 3000 psi pressure. Rated output flows from 0.1 to 50.0 GPM for control currents of from 2.0 to 40.0 milliamperes as specified are available in production units.

Conventionally the valve input is from a balanced push-pull DC amplifier and the valve flow output is applied to a piston or hydraulic motor. An electric signal proportional to piston position or motor angular rotation is fed back to the amplifier to give a closed servo loop.

Typical applications for these units are in servo systems used for guided missile and aircraft flight controls, radar scanner actuation, contour following machine tools, and automatic packaging equipment.

For details write for Bulletin 2000-2

MOOG VALVE CO., INC. PRONER AIRPORT EAST AURORA, N. Y.

tric window-openers, special lighting, and spiral elevators in his homes. On the lawn of his Kings Point house a giant bronze eagle turns to face approaching ships, and at the touch of a button emits a recorded eagle scream.

Monsanto Gets First 702

Monsanto Chemical Co. became the first customer for IBM's huge 702 electronic data-processing machine. The equipment, just delivered to St. Louis, will soon take over the task of computing Monsanto's 1,200 monthly cost reports. In 30 sec it can handle a report that would take an accountant 2 hr to process.

Speeds Ram-Jet Tests

Marquardt Aircraft Co. now expects to assay its ram-jet tests three times as fast as before, thanks to a $160,000 electronic data processor installed by Consolidated Engineering Corp. The system converts 400 instrument readings per sec into digital data and stores them on magnetic tape.

Supersonic Simulator

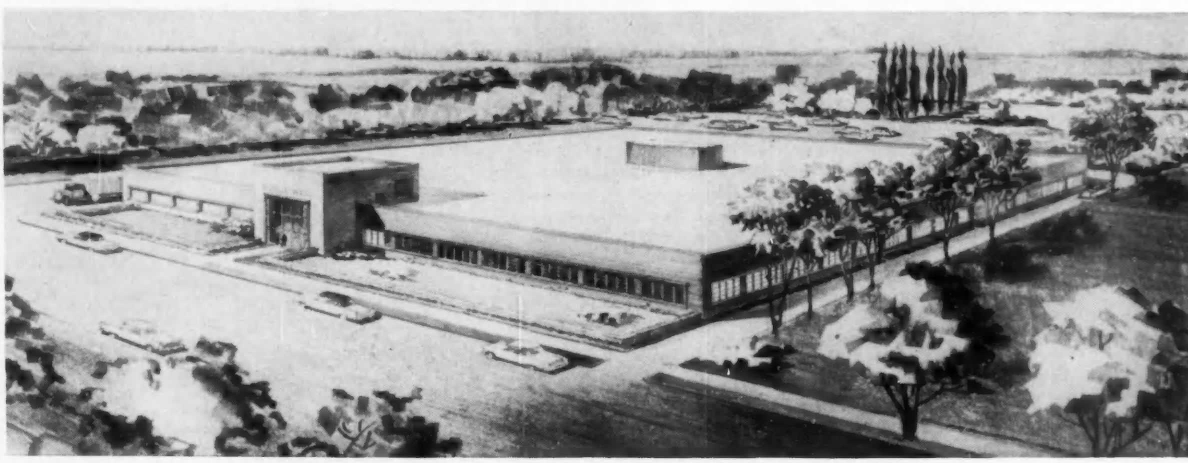
Air cadets can now enjoy all the thrills of supersonic flight without leaving the ground. The U. S. Air Force has installed its first supersonic flight simulator, the F-100A, made by Westinghouse Air Brake Co. The machine consists of seven major assemblies and five electronic computer racks, occupying a total space of 47 by 18 ft.

Titillates Toy Fair

The world's "smallest almost-automatic computer" made its debut at the New York Toy Fair. It is a parts kit, which can be assembled by youngsters into the Geniac, a computer that performs arithmetic, solves logical problems, decodes messages, and even plays tic tac toe. Geniac's brainfather is Oliver Garfield, a 27-year-old teacher who developed his machine with the help of New York consultant Edmund C. Barkley. In addition to being uncommonly small and simple, Geniac is inexpensive as computers go—only $15.95.

Computer Courses

The Computation Laboratory of Wayne University plans four consecutive week-long summer cram courses. Starting June 6, they cover: (1) Electronic Computers, Business and Engineering Applications; (2) Automatic Data Processing; (3) Mathematical Programming of Management Problems; and (4) Numerical Methods and Advanced Programming Techniques. For further information write to A. W. Jacobson at the laboratory in Detroit.



There will be 150,000 sq ft of space in Minneapolis-Honeywell's $1,750,000 factory in Morton Grove, consolidating Chicago operations.

Around the Business Loop

▶ **Norden-Ketay Corp.** has acquired **Acragage Corp.** Production of Acragage's quality pressure and vacuum gages will be supervised by Robert F. Carleton, general manager of the New York City and Hawthorne, Calif., plants. (Norden-Ketay's 1954 net sales totaled $9,086,453, down somewhat from 1953. Its net profit was $1,002,-992 or $1.01 a share.)

▶ **Hycor Companies** of California and Puerto Rico have been taken over by **International Resistance Co.** but will continue to operate independently.

▶ **Quality Control Engineers, Inc.,** which will establish quality control systems and conduct evaluation surveys for aviation and electronics, has been formed in Los Angeles.

▶ **Texas Apparatus Co.** of Houston, a new company, brings to the southwest for the first time an engineer-producer of electrical distribution apparatus, process control panels, materials handling equipment and specialty fabrications. William E. Brice is president.

▶ **General Controls Co.** will buy the Controls and Instrument Div. of **Perflex Corp.** For the present, the division will operate under the Perfex name with no change in management.

▶ **Penn Industrial Instrument Corp.** has become a division of **Burgess-Manning Co.** Former Penn President William C. Bennett, elected vice-president and director of Burgess-Manning, will manage the new division.

▶ A systems engineering group to act as electronics consultant to industries concerned with automatic production and quality control has been formed by **Du Mont Laboratories.** Projects already in view include the design of automatic test and control systems for oil and gasoline refineries, and for production of metal alloys, metal cables, plastics, paint, electrical and electronic products.

WHAT'S NEW

SAFETY FIRST: Scottdale, Pa. plant of Robertshaw-Fulton Controls Co. took a first place in a nationwide industrial safety contest. Holding plaque are, left, A. J. Stinebiser, plant superintendent, and Steve Hollis, president of Scottdale Local 3964, CIO-United Steel Workers.

▶ **Universal Winding Co.** has established a Nuclear Engineering Department in Jamaica, N. Y. Dr. Cecil B. Ellis, founder and former president of Atomic Power & Chemicals Corp., will head the department as director of nuclear engineering.

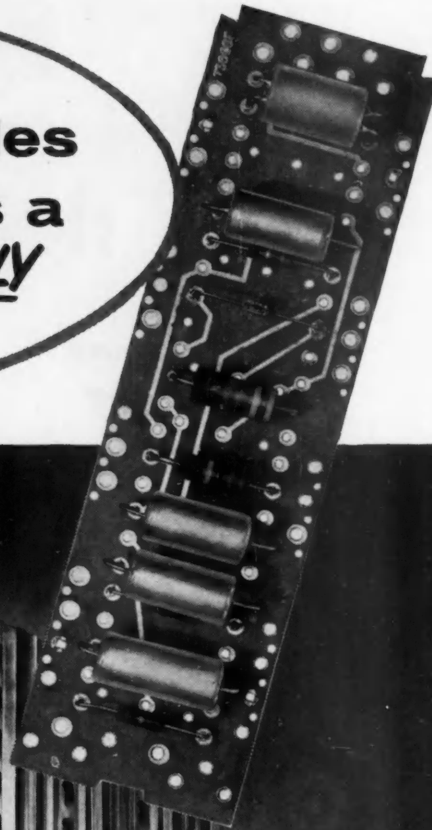
▶ Abstracts of current articles and books about electronic data processing are being carried in **Canning, Sisson & Associates'** Data Processing Digest. The new service is $24 a year.

▶ Mock-ups of new aircraft models will be shown in the new engineering controls laboratory going up at the El Segundo, Calif., Div. of **Douglas Aircraft Co.** The laboratory will contain an electronic computer for developing and analyzing aircraft flight and fire control systems.

▶ **Magnavox Co.** plans to expand its new research laboratories in West Los Angeles and has appointed Dr. Ragnar Thorenson, who directed work on the SWAC digital computer at U.C.L.A., and Dr. John Salzer, formerly with M.I.T. and Hughes Aircraft, director and assistant director of research, respectively.

▶ **Minneapolis-Honeywell** will build the monitoring and recording equipment for the control system of the chemical processing plant at the AEC's national reactor testing station. Radiation detectors and ion chamber units are included in the order. **Blaw-Knox,** chemical plants div., Pittsburgh, Pa., is the design engineer.

Autofab assembles 20 of these circuits a minute... AUTOMATICALLY



Here's a machine that can automatically assemble any unit calling for standard electronic components—including tube sockets and I.F. cans—on a printed circuit card. *Autofab* gives you fast, low-cost production of complex assemblies, and it offers many unusual features:

SELF INSPECTING! Besides turning out completed circuits at remarkable speed (1,200 per hour), *Autofab* does its own "inspecting" and refuses to pass any but perfect mountings.

FLEXIBLE! The length of the machine can be varied to fit production needs. And switching from one circuit assembly to another is a fast, easy job. *Autofab* assembles components flat against the boards with leads bent in any direction, or offsets them from the board—or both.

COMPONENTS EASILY HANDLED! *Autofab* feeds components individually from big 8-magazine turrets. Polarized components are kept in alignment automatically.

NO MOUNTING OF CIRCUIT CARDS! *Autofab* positions cards accurately with no lost motion.

EASY TO INSTALL! Standard electric power and compressed air are all you require to power *Autofab*. And its simple mechanical linkages are easy to maintain.

Full details on Autofab *will be gladly sent on request to Dept. C-7, Mechanical Division of General Mills, 1620 Central Avenue, Minneapolis 13, Minnesota.*

Autofab is a G.M.I. trademark

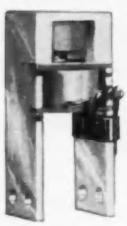
THIS 24-HEAD *AUTOFAB* MACHINE is now at work for IBM helping to produce printed circuit assemblies for use in air defense computers. Other models are now available for producing circuits used in radios, television sets and other electronic devices.

MECHANICAL DIVISION OF General Mills, Inc.

Job opportunities available for creative engineers. Work closely with outstanding men on interesting projects.

PERFORMANCE IS BUILT INTO THIS CHOPPER

Painted case resists corrosion and is hermetically sealed to the base so that this chopper operates reliably in any atmosphere from sea level to 50,000 feet.



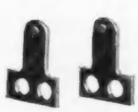
Permanent magnet polarizes switching to provide phase sensitive mechanical modulation of low-level signals.

Drive coil is conservatively rated for 6.3 volts RMS $\pm$ 10% at 400 CPS $\pm$ 5%.

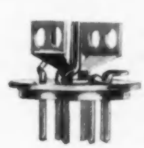
Vibrating reed is resonant well above operating frequency to assure that switching phase of 65 degrees remains within $\pm$ 15 degrees for all operating conditions.

Buffer plate counteracts any tendency to chatter at make and break.

Ceramic insulators provide at least 100 megohms between contacts and case for use in high-impedance circuits.



Wiping action on fixed contacts, as in all Airpax choppers, help assure rated life of 2,000 hours.



Miniature 7-pin tube-type base rigidly supports internal assembly of this Airpax Type 300 chopper so that it withstands shock and vibration.

For complete specifications write to

DESIGNERS AIRPAX PRODUCTS COMPANY ENGINEERS

MIDDLE RIVER BALTIMORE 20, MD.

Valparaiso, Indiana, April, 1955 — The Indiana Steel Products Company, world's largest manufacturer of permanent magnets, has released information on the development of an important new product...a one-piece wound core.

Called the "Hyflux," its applications are the same as conventional C-type cores...distribution, welding, X-ray, lighting, and special transformers and saturable reactors.

The one-piece core consists of just one piece  instead of two pieces  as in the conventional C-type cores.

Because the one-piece core has but one air gap, instead of two, there is definite improvement in performance...and exciting current is normally lower, often by a significant amount. Vacuum impregnating is not necessary (only the sides of one-piece cores are varnished) and resulting electrical losses are eliminated.

Manufacturers using the new cores find that the simplified one-piece design cuts down assembly time, and permits important assembly cost reductions.

With C-cores, the two halves must be kept and used together to insure a flush fit of their ground pole faces...with one-piece cores there is no chance of mixing different pairs of halves. Nor is there the slight "tilt" sometimes present on the ground pole faces of C-cores.

Substantial manufacturing economies resulting from the new design are reflected in the price of the one-piece core.

So convinced is Indiana Steel that its new core will benefit transformer manufacturers that it has entered the magnetic core field...after 46 years of specializing in permanent magnets.

Hyflux "one-piece" wound cores are now available in the more popular 12-mil standard core sizes. You are invited to write for descriptive literature to: The Indiana Steel Products Company, Dept. P-5, Valparaiso, Indiana.

Only operation required on Kemp Oriad Dryer is moving lever once a week to switch flow of air to second column. First column is reactivated by heat during the week.

How Kemp assures round-the-clock operation at Spencer Chemical

The Spencer Chemical Co., Charlestown, Ind., operates 24 hours a day, 7 days a week, making nitrogen compounds for the fertilizer industry. Heart of this operation is the master instrument board that controls all plant processes. These instruments are operated by compressed air, which must be dried to prevent rust and corrosion within the controls.

Kemp Offers Continuous Protection

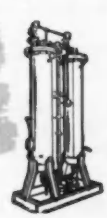
Spencer uses a Kemp Oriad Dryer to dry all the air required and completely protect the delicate instruments from moisture damage. Since its installation in 1950, this Kemp unit has needed no service of any kind. And Spencer is delighted with Kemp's ease of operation! Mr. N. S. Whitaker, Works Manager, commenting on Kemp's "most satisfactory service," says, "Operation is simplicity itself. All we have to do is switch a lever once a week. Capacity is ample for one week of maximum flow, on a 24-hour 7-day operation."

Kemp Dryers for Every Purpose

Kemp offers a variety of dryer models to meet all problems. Designed to dry air to sub-zero dew points at low cost, these efficient dryers embody the engineering knowledge gained from Kemp's many years of experience. They are available with manual, semi-automatic, or fully automatic tower reactivation. In addition, Kemp will prescribe the proper desiccant for each specific drying job. If you have a problem involving the drying of air, gases, or liquids, contact Kemp engineers now.

For more complete facts and technical information, write for Bulletin D-27 to: **THE C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.**

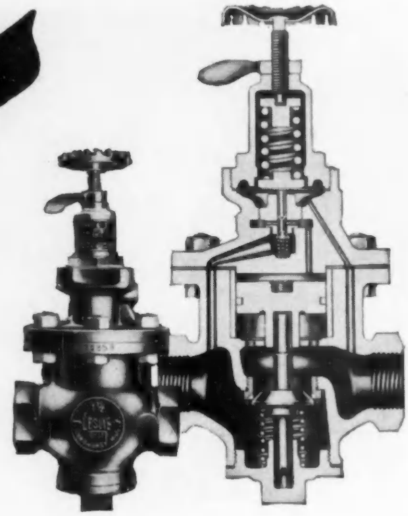
KEMP OF BALTIMORE



DYNAMIC DRYERS

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • INERT GAS GENERATORS
SINGEING EQUIPMENT

the
PRESSURE'S ON!



STEADILY,
CRITICALLY,
AUTOMATICALLY, with

LESLIE

PRESSURE REDUCING VALVES

No need for costly, complicated two-stage reducing stations when you handle high pressure drops with Leslie Pressure Reducing Valves . . . *ideal* for steam heating installations or for process reductions.

Leslie design, materials and workmanship have proved successful for more than 55 years in all kinds of industrial heating applications. The single-seated, internal pilot, piston operated construction of Leslie regulators can handle pressure drops up to 1500 psi and higher and are being used successfully in pressure generating stations all over the U. S.

Send for the bulletin described below today.

- **For Steam, Air, Gas**
- **99% Accuracy of Regulation**
- **Instant Reaction to Flow Change**
- **Stellited Seating Surface**
- **Positive Dead-End Shut-Off**
- **Interchangeable Parts**

TYPICAL PRESSURE RANGES

CLASS	BODY MATERIAL	SIZES	INLET STEAM PRESSURES	REDUCED PRESSURE RANGE
LLK	Cast Iron	½"-6"	25-250	2-35
LK	Cast Iron	½"-6"	25-250	10-235
LL-3	Cast Bronze	½"-4"	25-300	2-35
L-3	Cast Bronze	½"-4"	25-300	10-285
LL-4	Cast Bronze	5"-6"	40-300	5-35
L-4	Cast Bronze	5"-6"	40-300	20-275
IS-2	Cast Carbon Steel & Cast Alloy Steels	½"-3"	300-750	100-600
HS-3		1"-3"	300-1500	100-600

BULLETIN 5302

Provides latest engineering data on all classes of Leslie Pressure Reducing Valves—assists you in planning and specifying for optimum performance. Yours on request.

TRADE LESLIE MARK

LESLIE CO., 211 Grant Avenue, Lyndhurst New Jersey

HARDENED *and* GROUND

DOUBLE ENVELOPING WORMS *and* Worm Gears

The Vard-designed worm grinder now makes it possible to produce steel double enveloping worms which are ground after carburizing with a contour that cannot be matched by any other method. Carburizing the rough blank also produces a surface hardness of over 60 Rockwell C scale with a depth of .025 to .035 of an inch on the finished worm. The finish maintained is 16 microinches RMS or better. The carburized steel worm also offers high resistance to fatigue failures due to the pre-stressed surface.

INTERCHANGEABILITY

The teeth of the worm gear are cut by a hob which is ground using the same machine setup as that used to produce the worm. This method results in interchangeable parts rather than the lapped, matched sets produced in other types of manufacture.

HIGH EFFICIENCY

The accuracy attained by the exclusive Vard process provides a combination of true geometry and surface hardness that assures higher efficiency for longer periods of time than comparable gear sets fabricated by other methods.

ACCURACY AND CONTROL

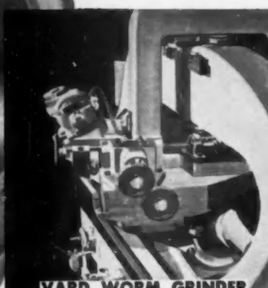
Backlash may be controlled to within .0005 of an inch or less, if necessary, which makes Vard worm and gear sets ideal for instrument and control drives.

CUSTOM DESIGN

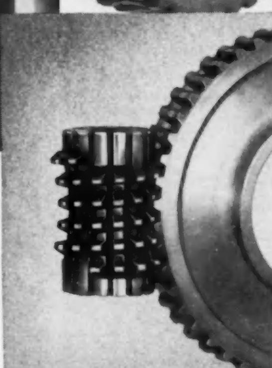
At present Vard is equipped to manufacture worm and gear sets in any quantity in a range of center distances from 1 to 8 inches.

For further information, write for Engineering Data Booklet No. 1002.

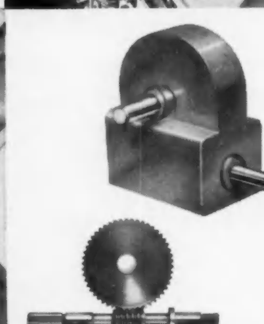
Vard, Inc. 2981 East Colorado Street
Pasadena 8, California



VARD WORM GRINDER



WORM GEAR HOB



SERVO OR MINIATURE CONTROL COMPONENTS

INDUSTRIAL GEAR BOXES

FIRST in custom gearing

VARD

New

TRANSISTORIZED MINIATURIZED

TYPE 2007T

400 CYCLES ±.02%

28 VOLTS D.C.

SPECIFICATIONS

INPUT
20 to 35V DC
at approx. 5 m.a.

OUTPUT FREQUENCY
400 or 500 cycles

Type 2007T
+ —.02% from —65° to + 85°C.

Type R2007T
+ —.002% from + 15° to + 85°C.

Type W2007T
+ —.005% from —65° to + 85°C.

OUTPUT VOLTAGE
5 volts, sine wave.

Substantially uniform
from —65° to + 85°C.

LIFE EXPECTANCY
several times that of vacuum tubes

INTERNALLY SHOCK MOUNTED
on Silastic

MAGNETICALLY SHIELDED

HERMETICALLY SEALED

OCTAL BASE

SIZE
4½" x 1½" diameter

WEIGHT
7 ounces

COMPLETE INFORMATION ON REQUEST
PLEASE SPECIFY TYPE 2007T

Precision

FREQUENCY STANDARDS

These units, which are the result of several years of development and testing, offer a new standard of simplicity and reliability. Particularly noteworthy is the uniformity of output signal voltage with temperature change. Small size and light weight make them ideal for airborne and portable use.

For applications where only higher B voltages are available, a simple voltage reducing circuit may be used.

American Time Products, Inc.

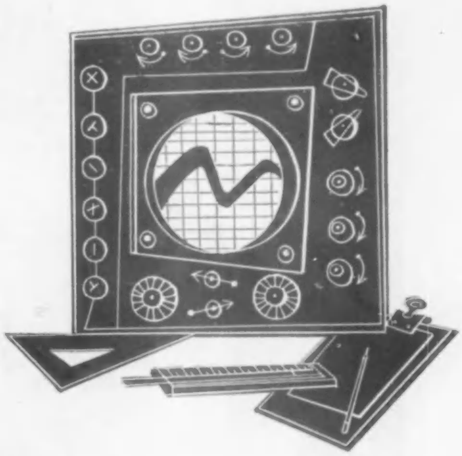
580 Fifth Avenue ***New York 36, N. Y.***

MANUFACTURING UNDER PATENTS OF WESTERN ELECTRIC COMPANY

ENGINEERING
There are Qualities
Behind ANNIN VALVES
you'll never find
in imitations
RESEARCH
& DEVELOPMENT
ANNIN
QUALITY
CONTROL
EXPERIENCE

INDUSTRY'S PULSE

Management Eyes – Then Buys – Computers



Computers and data processing face a prodigious future. Last summer Stanford Research Institute forecast a twentyfold sales growth to $500 million by 1960. Today even this figure looks conservative.

The potpourri of news on recent digital doings hints at this future. In November C&O Railroad elected Univac to unsnarl its yearly crop of 1 billion pieces of paper. Shortly after, GE's Carbology Division put 2,500 inventory items under the wing of an IBM system. ElectroData next installed the Mobilac to impersonate a Socony-Vacuum refinery. And Engineering Research Associates recently perfected its electronic central file for nationwide CAA air traffic control.

They've put them to work on gigantic projects

But even more revealing than this functionally diverse, big-firm pioneering is the acute, almost aggressive interest in computer systems by management people in all types and sizes of companies from coast to coast.

This interest in computers came to white heat during a recent American Management Association forum in New York. Despite the stiff $75 fee, some 1,264 executives from over 600 different companies grouped for confabs on system planning, programming, and performance. The lure: some unvarnished user facts aired by people from their own ranks. The semantics were unclouded, the economics down to earth.

What group in management is studying computers? Titles of AMA attendees proved one-half were comptrollers, one quarter treasurers, the rest mainly systems specialists. They came from varied firms, but the concerted interest was obviously from banking, insurance, utilities, and transport–industries traditionally harassed by paper work.

They want the facts—but from the user

What questions do potential computer buyers ask? AMA queries were sharp and to the point. Why did you select the particular system you bought? How much does it cost you to operate? How much time do you spend in maintenance? What future operations do you plan?

But the recurring and obviously bedeviling question was: What type of people will run the computer and do its programming? Your own employees, or need you drag in trained newcomers? The happy consensus was that existing employees who

are familiar with company operations are best for the job. These could be trained to program a computer in five or six weeks. Outsiders, although skilled in the machine, often flunk in learning how it fits the company.

Who will maintain the complex computer facility is more of a moot question. Some management makes no bones about the need for outside specialists here. Allstate, for example, has hired a man with a physics degree to keep up its Datatron installation.

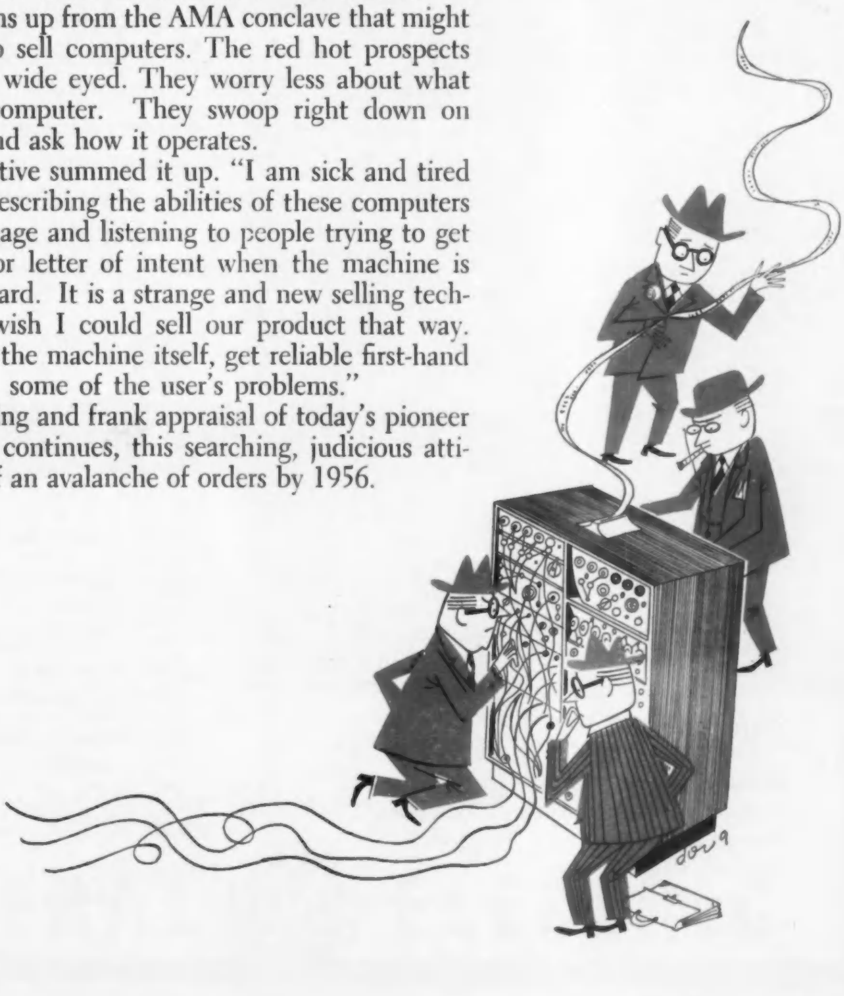
Management knows enough today to be sharply critical of existing computer equipment. Principle gripes—aside from the universal lament about high cost—seem to hover about access time and related aspects of data storage. One claim is that drums are too costly for herding large masses of small accounts. And tape is generally inconvenient for fast random access.

They're more squinty, less wide eyed

One strong fact looms up from the AMA conclave that might well guide people who sell computers. The red hot prospects are more squinty, less wide eyed. They worry less about what they can do with a computer. They swoop right down on the equipment itself and ask how it operates.

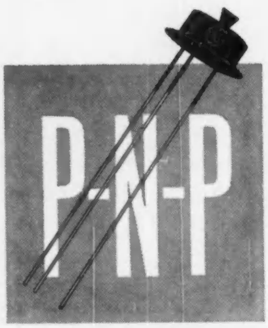
A prospecting executive summed it up. "I am sick and tired of reading brochures describing the abilities of these computers in a very strange language and listening to people trying to get me to sign an order or letter of intent when the machine is still on the drawing board. It is a strange and new selling technique to me. I only wish I could sell our product that way. Frankly, I want to see the machine itself, get reliable first-hand information, and learn some of the user's problems."

And if the avid visiting and frank appraisal of today's pioneer computer installations continues, this searching, judicious attitude can well touch off an avalanche of orders by 1956.



G.E. MECHANIZED PRODUCTION AT LOWER COST...ASSURES

Both types offer high reliability at temperatures



TYPE 2N43A

Take a close look at the transistor values G.E. now offers. Because production lines are now mechanized, these transistors are made in *less time* at *reduced cost.* Machine methods today assure strictest adherence to the top quality standards demanded of all General Electric Germanium Products.

Mechanization results in CONTROLLED CHARACTERISTICS, removing any inaccuracy on the part of the operator. Narrow limits are built into production transistors giving a more uniform product.

In military and commercial applications these G-E transistors offer precision quality, topmost reliability at mass-volume prices!

General Electric's P-N-P junction transistor, 2N43A, is the first to be written into Air Force specifications! MIL-T-25096 (USAF) was actually written around this G-E product which was developed for the military. Now it serves an ever-increasing number of commercial as well as military applications.

APPLICATIONS AND SPECIFICATIONS

TYPICAL USES: Audio and Intercom Amplifiers, Servo Amplifiers, Carrier Current Amplifiers, Test Equipment, Fuel Gauges.

SPECIFICATIONS OF THE 2N43A and USAF 2N43A

Absolute Maximum Ratings:

Collector Voltage (Referred to base)	−45 volts
Collector Current	−50 ma
Collector Dissipation	150 mw
Storage Temperature	100° C
Collector Cutoff Current (−45 volts)	−10 microamps

DESIGN FEATURES:

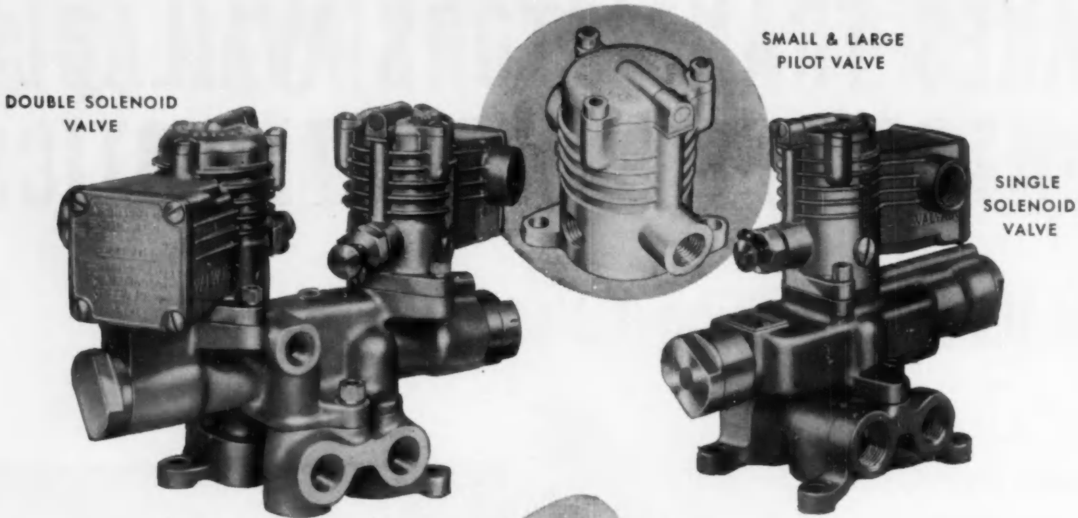
STURDY CONSTRUCTION...meets critical military tests for shock, vibration, humidity, life.

SEALED JUNCTION...contamination gases permanently eliminated!

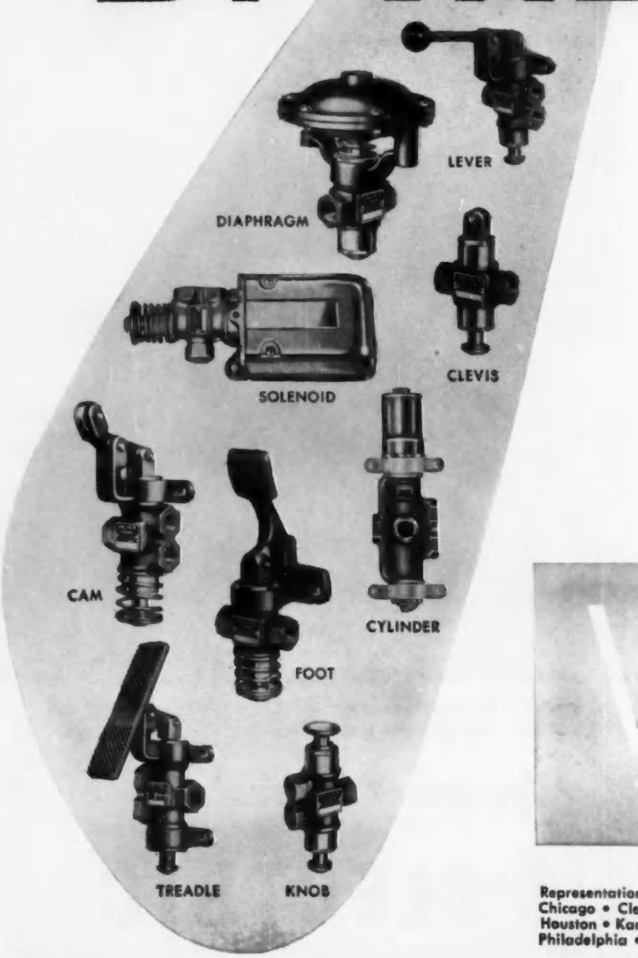
HIGH POWER OUTPUT...case design makes possible a collector dissipation of 150 mw.

HERMETIC SEAL...unaffected by moisture.

LONG LIFE...no change in characteristics during life of equipment.



AIRMATION BY VALVAIR



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Control ENGINEERING

MAY 1955

Let's Pull Together—Again

Our March editorial counseled control engineers to support and coordinate the activities of existing professional societies rather than to form a new group of their own. Reader feedback was immediate, strong, and sustained. This quotation from one letter sums up the general feeling: "Let's not even consider starting a new society. There is plenty of room in the present organizations for everybody."

The same editorial pointed out the most recent efforts of the existing societies to provide *new* activities that serve the control engineer. We referred to the *first* technical session of the IRE Professional Group on Automatic Control and the *first* divisional conference of ASME's Instrument and Regulators Division. Both events took place this spring.

Although these events are evidence of new awareness of the control engineer's needs, our editorial did not mention the continuous work of other societies. But their loyal members did — quickly and forcefully. A case in point is the conference held by AIEE's Feedback Control Committee last year in Atlantic City. We are told that the conference will be repeated, complete with enlarged exhibits of working control systems, in the spring of 1956.

Members of the Instrument Society of America hastened to direct attention to services rendered. ISA President Warren H. Brand writes, "The performance and plans of ISA are of sufficient importance to deserve the considerable support of control engineers." With a membership including technicians, professional engineers, and management, the Society "believes that there is a place for all levels of technical interest in the broad and expanding field of automatic control." Certainly the large number of sessions that ASME, AIEE, and IRE will co-sponsor at the Tenth Annual ISA Conference demonstrates a strong cooperative program at a professional level.

Our trial by feedback shows a persuasive reader unity in rejecting thoughts of a new society. We should like to see more of this unity in cooperative efforts among existing societies. The wholehearted support of the American Standards Association's terminology committee by all technical organizations interested in the terminology of our field is a healthy sign. Additional teamwork could show up through cross-membership in the professional divisions concerned with control, through combined educational programs at national and local levels, and through operational clinics. The results can only be to mutual advantage.

We repeat — Let's pull together.

THE EDITORS

YOU NEED NO COMPUTER TO

Graphically Determine the Dynamics of Heat Percolation

THE GIST: Consider a pipe that transports a heating or cooling fluid. To perfect a thermal control system incorporating the pipe, the control engineer needs to be able to determine its outlet temperature transient response to:

- inlet temperature change
- internal flow rate change
- variation in heat loss due to changes in external flow rate and external temperature distribution
- variation in parameters such as coefficients of heat transfer

Mathematical analysis of the response, although possible, is difficult and tedious. However, the piecewise response to each disturbance can be constructed graphically. Programming accounts for non-uniformities and variations in parameters.

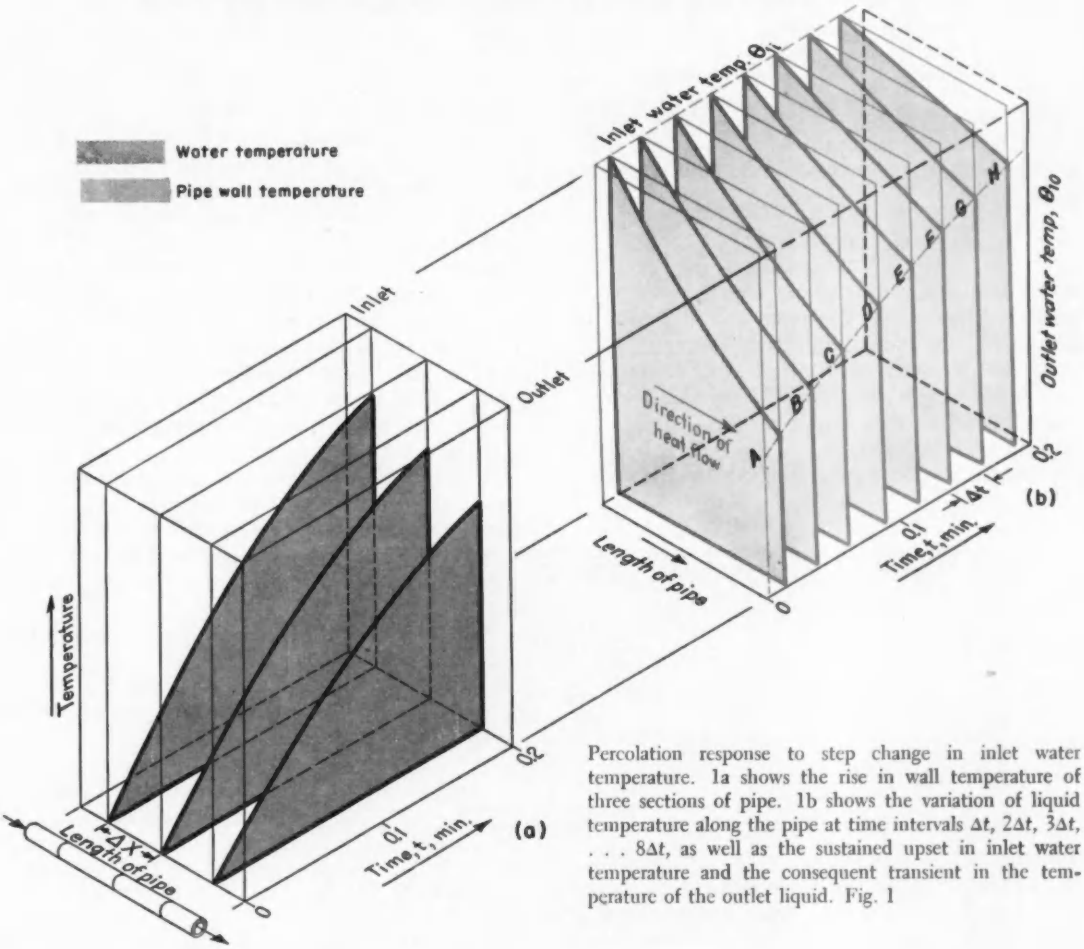
This article considers the outlet temperature response to only inlet liquid temperature change. A forthcoming article will show the generalized construction for the other disturbances.

YASUNDO TAKAHASHI, Professor, University of Tokyo, and Fullbright Scholar, MIT

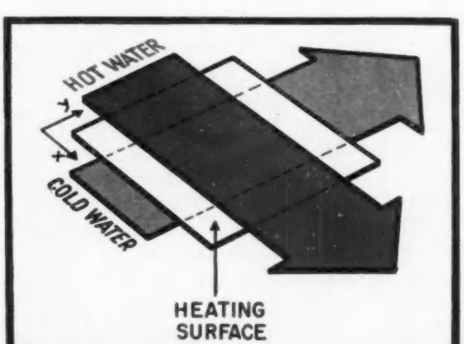
After a sudden increase in temperature of a liquid entering one end of a pipe, the temperature of the liquid at the pipe's outlet does not rise for the time required to transport the liquid the length of the pipe. This time is called "distance-velocity lag." As soon as the transportation is complete, a hot front, attenuated by the cold pipe, pours out. Then as each section of the pipe warms, Figure 1a, the outlet temperature rises exponentially to its final value along the curve A-B-C-D—in Figure 1b. The phenomenon is called "percolation" because similar dynamic behavior occurs in material exchange.

Mechanical engineers first highlighted the phenomenon in the last century when they discussed the heat storage effect of the passage between a steam engine's slide valve and cylinder. The passage cools the supply steam and heats the exhaust steam, thus decreasing thermal efficiency. Another classical example is the regenerative heat exchanger. Its operation depends entirely upon percolation. The exact solution of this type of temperature field was first suggested by the German physicist W. Nusselt[1], in his analysis of crossflow heat exchange. Nusselt solved for the equilibrium temperature distribution of the crossflowing fluids functionally shown in Figure 2. Most interesting, the equilibrium temperature distribution of crossflow fluids is identical to the three-dimensional (temperature, space, time) distribution in Figure 1 if one replaces time by the flowing distance, Y, of the colder fluid of Figure 2. Published more than 30 years ago, Nusselt's solution is difficult to handle numerically. But the

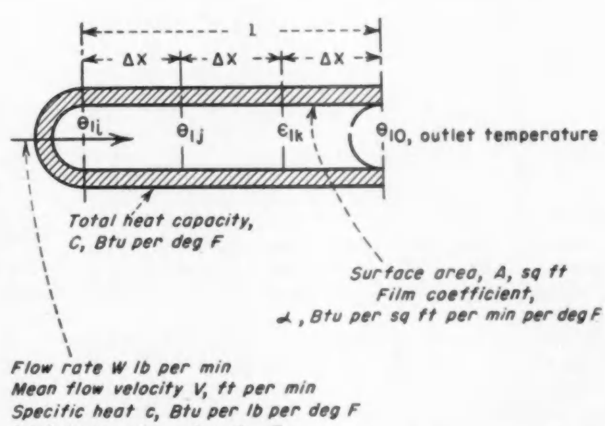
PIPE DYNAMICS AND TERMINOLOGY



Percolation response to step change in inlet water temperature. 1a shows the rise in wall temperature of three sections of pipe. 1b shows the variation of liquid temperature along the pipe at time intervals Δt, $2\Delta t$, $3\Delta t$, . . . $8\Delta t$, as well as the sustained upset in inlet water temperature and the consequent transient in the temperature of the outlet liquid. Fig. 1



Crossflow heat exchange. Figure 1 describes the equilibrium temperature distribution, if dimension Y replaces the time coordinate. Fig. 2



Definition of symbols Fig. 3

problem is simple if tackled graphically.

The Graphical Method

Figure 3 defines the parameters, C, α, A, W, c. Combine them in the factors:

$$\frac{C}{\alpha A} = T \text{ (min)}, \quad = \quad \frac{\alpha A}{Wc} = R \text{ (dimensionless)}$$

Divide the tube length, l, into N sections and the reaction time into intervals Δt min in such a way that the following dimensionless numbers are less than 0.3,

$$a_1 = \frac{\Delta t}{T}, \qquad a_2 = \frac{R}{N}$$

Then follow the construction sequence shown in Figure 4. Example: A copper pipe 1.25 in. od, 1.084 in. id, and 14 ft long carries water.

The heat capacity of the pipe is C = (specific heat) (total weight) = 1.5 BTU per deg F.

Internal surface area, A is 4 sq. ft.

Taking a film coefficient α of 3.8 BTU per deg F sq ft min for a water flow rate of 2 gal per min,

$$T = \frac{C}{\alpha A} = \frac{1}{10} \text{ min}$$

The water's heat capacity, Wc = 16.6 BTU per deg F per min.

Hence, $$R = \frac{\alpha A}{Wc} = 0.9$$

As the water's mean velocity is 42 ft per min, the dead time, (length/velocity), = 14 ft/42 ft per min = $\frac{1}{3}$ min. Taking Δt = 1/40 min and N = 3,

$$a_1 = \tfrac{1}{4} \qquad \text{and} \qquad a_2 = 0.3$$

Figure 4 shows the graphical construction of the outlet liquid response to a sudden change in the temperature of the liquid admitted to the pipe.

In Figure 5 the curve O-A-B-C-D—shows the result of the complete graphical construction, preceded by a distance-velocity lag, L = $\frac{1}{3}$ min.

The approximate transfer function of the step response is:

$$G(s) = K_1 + \frac{K_2}{1 + T_1S} = \frac{1 + K_1T_2S}{1 + T_1S} \qquad (1)$$

where

K_1 = OA = 0.4 in Figure 5 and $K_1 + K_2 = 1$

From Figure 5, T_1 scales equal to 0.14 min. Then T_2 = 0.056 min.

The appendix shows the derivation of approximate transfer functions of the same form, obtained by lumping the pipe's heat capacity—that is, by neglecting the pipe's temperature gradient in the direction of flow. The system parameters then give the time constants directly:

$$T_1 = RT(1 - e^{-R}) \qquad \text{and} \qquad T_2 = \frac{RTe^{-R}}{(1 - e^{-R})} \quad (2)$$

Applying the numerical values given in the example,

$$T_1 = 0.15 \text{ min}, \qquad \text{and} \qquad T_2 = 0.06 \text{ min}$$

This gives a step input response that practically coincides with the curve of Figure 5. In the graphical solution the heat conductivity of the pipe wall in the direction of flow was assumed zero, while in the approximate solution it was assumed infinite. The close agreement between the two results leads to these deductions·

► Conductivity of the pipe wall in the direction of flow does not play an important role[2].

► The simpler formulae (1) and (2) are adequate except when R is very large.

In such extreme cases the graphical solution is the simplest way to get the transient response.

But more important, by graphics we can handle cases of non-uniform or non-constant system parameters. Shifting the reference lines' positions takes into account these effects and reveals a way to solve for response to flow-rate change. In liquid flow, the flow-rate changes simultaneously over the entire pipe length; hence we can calculate a_1 and a_2 for each time interval from the mean values of W and α for each Δt.

If there is heat loss the flow rates affect the steady temperature distribution of the pipe wall. Therefore, a step flow rate change causes an outlet fluid temperature response. The graphical solution of this response is little different from that in Figure 4 except that

(a) we have to start from a given pipe wall temperature distribution,

(b) the pipe wall temperature is affected not only by the fluid temperature in the pipe, but also by the external fluid temperature.

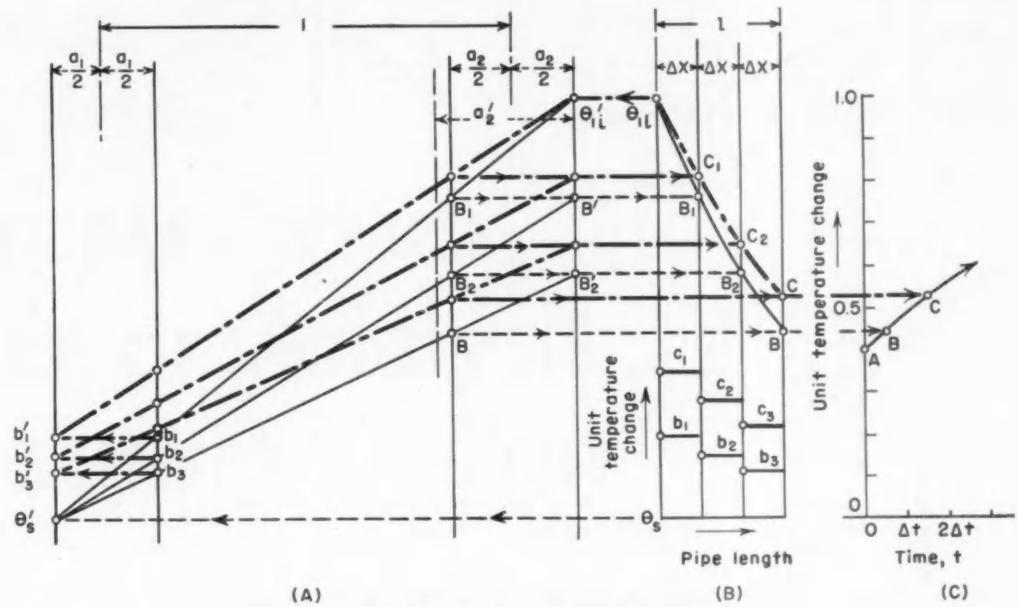
P. Profos[3] developed the exact frequency response of percolation in his thesis on steam superheater control by water injection. The formula is

$$G(j\omega) = e^{-\frac{R(\omega T)^2}{(\omega T)^2+1}} \Big/ -57.3\,\frac{R(\omega T)}{(\omega T)^2 + 1} \qquad (3)$$

Inserting the given values of system parameters, we get the frequency response shown by the solid lines in Figure 6. The dotted curves in the same figure are calculated from equation (1). Equations (1) and (3), and hence Figure 5, do not include the phase shift due to the distance-velocity lag, L. This phase shift equals $-57.3WL$ deg. In the example, $L = \frac{1}{3}$ min and the resulting phase shift exerts a much more powerful influence on control system behavior than does percolation.

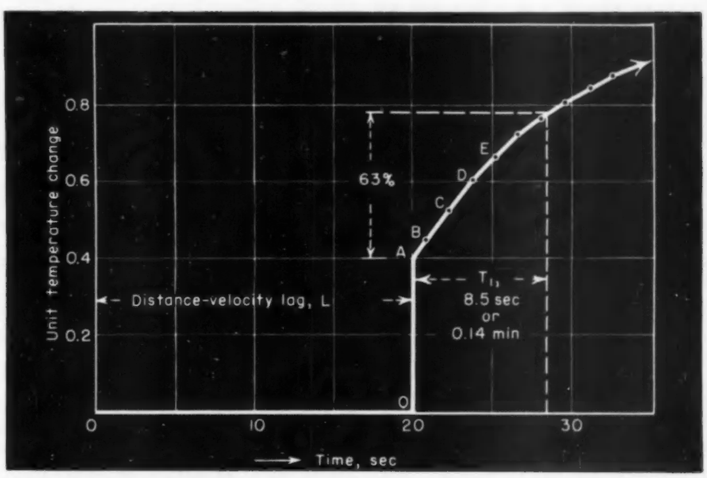
It is possible to account for finite conductivity in a radial direction[4] but numerical calculation with the final equation is not easy. The author suggests the use of the simpler equations up to equation (3), taking the equivalent value of pipe capacitance estimated from the effective wall thickness.

A uniform velocity distribution on all pipe cross sections has been assumed. This is not a strictly valid assumption. Further experimental studies on this point should give a clue to a closer prediction of percolation effects.



TYPICAL GRAPHIC CONSTRUCTION . . . Fig. 4

. . . AND ITS RESULT



Step input response of percolation plus distance-velocity lag. Fig. 5

Displace four parallel lines in the ratio $[1 + (a_1 + a_2)/2] : a_1 : a_2$, as in 4a. Pipe wall temperature plots vertically, and pipe length horizontally in 4b.

First Time Interval, $t = o^+$ to Δt

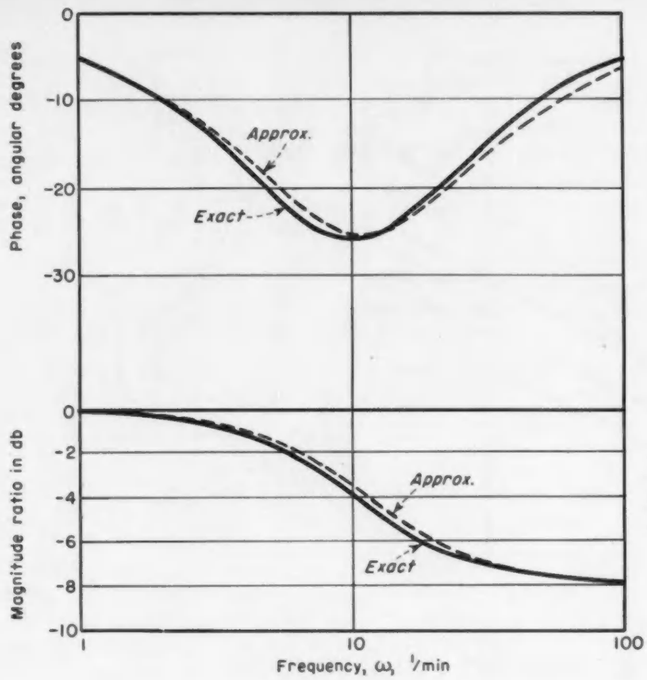
Transfer initial pipe wall temperature, θ, and inlet liquid temperature θ_1 at time $= o^+$ to θ'_1 and θ'_s, on the outer reference lines. A line between them locates B_1 and b_1 on the inner reference lines. B_1 is the liquid temperature at a distance ΔX from the inlet during the time interval $t = o^+$ to Δt and b_1 is the average pipe wall temperature from $X = o$ to $X = \Delta X$ at time $t = \Delta t$. B_1, transferred to the outer right-hand reference line, becomes B'_1, the initial liquid temperature for the second length of pipe. Connecting B'_1 with θ'_s locates, on the inner reference lines, B_2, the liquid temperature at 2 ΔX from the inlet, and b_2, the average pipe wall temperature from ΔX to $2\Delta X$. Transferring B_2 to the outer reference line and connecting the resulting B'_2 with θ'_s locates B. Projected to 4c, it is the average outlet fluid temperature for the first time interval.

Second Time Interval, $t = \Delta t$ to $2\Delta t$

The new temperature distribution of the pipe wall is $b_1 - b_2 - b_3$, but the inlet liquid temperature is still θ_1. Therefore the construction runs between θ'_1 and b'_1, b'_2 and b'_3 to find the liquid temperature distribution $C_1 - C_2 - C$.

The graphical cycle continues, step by step, to find the mean outlet temperatures D, E, etc. for each time interval Δt.

The outlet temperature, A, at $t = o^+$ is found by locating an auxiliary inner reference line at a distance $a'_2 = a_2\,[1 + (a_1 + a_2)/2]/[1 + a_2/2]$ from the right-hand outer line. The same graphical cycle solves for A. Fig. 4



Fequency response of percolation, minus the phase shift due to the distance-velocity lag. Fig. 6

DERIVATION OF FORMULAS

Denote the fluid and wall temperatures by θ and θ_s. Then the heat balance equation for finite differences is,

$$\frac{\Delta\theta_s}{\Delta t} = \frac{\alpha A}{C}\left[(\theta - \theta_s) - \frac{\Delta\theta + \Delta\theta_s}{2}\right],$$

$$\frac{\Delta\theta}{\Delta X} = \frac{\alpha A}{Wcl}\left[(\theta_1 - \theta_s) - \frac{\Delta\theta + \Delta\theta_s}{2}\right],$$

where $\Delta\theta$ and $\Delta\theta_s$ are finite differences from θ_1 and θ_s in Δx and Δt, and θ_1 is the fluid temperature θ before a change $\Delta\theta$ takes place. Solving these equations for $\Delta\theta_s$ and $\Delta\theta$, we have:

$$\Delta\theta_s = (\theta_1 - \theta_s)\frac{a_1}{1 + (a_1 + a_2)/2},$$

$$\Delta\theta_1 = (\theta_1 - \theta_s)\frac{a_2}{1 + (a_1 + a_2)/2}.$$

The spacing of reference lines in Figure 4a is based on this relationship.

If we lump the pipe wall capacitance, θ_s becomes independent of x. Therefore, integrating the equation

$$\frac{d\theta}{dx} = \frac{R}{l}(\theta_s - \theta),$$

we get

$$\theta_o = \theta_s + (\theta - \theta_s)e^{-R} \qquad \text{(a)}$$

Whereas, the heat balance for solid capacity is

$$Wc(\theta_i - \theta_o) = C\frac{d\theta_s}{dt} \qquad \text{(b)}$$

Eliminating θ_s from (a) and (b), and solving for $G(s) = \theta_o(s)/\theta_i(s)$, we get equations (1) and (2).

Assuming the conductivity of pipe wall zero in axial—and infinite in radial—directions, complete mixing and uniform velocity distribution of fluid in every cross section, and neglecting heat loss or generation, the basic heat exchange equations are

$$\frac{\partial\theta_s}{\partial t} = \frac{1}{T}(\theta - \theta_s), \qquad \frac{\partial\theta}{\partial t} + V\frac{\partial\theta}{\partial x} - \frac{R}{L}(\theta - \theta_s) \quad \text{(c)}$$

Assuming constant and uniform system parameters, the frequency response solution of this equation gives equation (3) plus dead time. Dead time is omitted from equation (3) to show pure percolation effect.

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FULBRIGHT SCHOLAR YASUNDO TAKAHASHI

Born on July 12, 1912 at Nagoya, Japan, Yasundo Takahashi took his Engineering Doctorate at Tokyo University in 1946. His thesis was "Regenerative Heat Exchange." Appointed Professor of the University that same year, he drew on this thermodynamics background to teach Japan's first automatic control course.

Modest, energetic Dr. Takahashi was the first chairman of the Automatic Control Div. of Japan's Society of Mechanical Engineers. He also served as director and chief editor of the Japan Society of Automatic Control. And he found time to write three textbooks, translate German control classics, and publish a host of automatic control articles both in and out of Japan.

Dr. and Mrs. Takahashi are now in Cambridge, Mass., where he still blends thermodynamics with feedback as a Fulbright exchange teacher.

IT PAYS TO USE Error Analysis During Design

Error analysis is the key to economical systems design. The techniques are straightforward, but they demand much effort. Here are some of the basic rules plus a tested procedure for thorough error analysis, involving these five steps:

1. ***Compare with ideal analog.***
2. ***Derive mathematical model.***
3. ***Choose best instrumentation.***
4. ***Subdivide and analyze.***
5. ***Add up the errors.***

WILLIAM ALLISON, American Bosch Arma Corp.

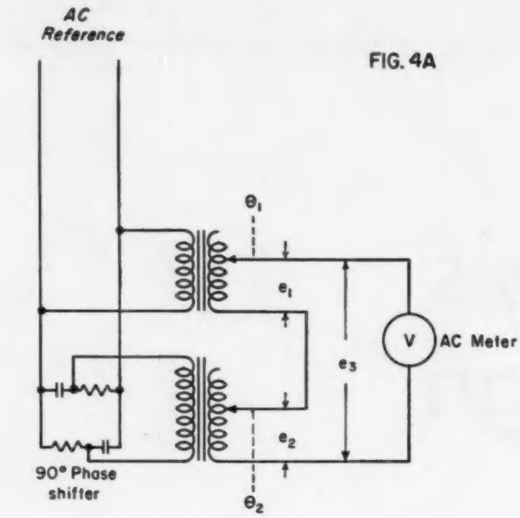
Analog system design must start with a thorough understanding of requirements and of the various ways of satisfying them, or the resulting equipment simply will not function. Servo design, system stability analysis, designation of component function, mechanical design, and circuit analysis must be considered as direct, in-line items of work which cannot be by-passed in the design of workable equipment. Elements that contribute to how well equipment operates or how much it costs or how long it lasts, however, are in a sense secondary matters.

Whatever the eventual importance of these secondary considerations, their development is inevitably retarded in favor of the in-line efforts. They include reliability studies, cost analysis, performance optimization, maintenance studies, and error analysis.

This area specifically establishes the ultimate competitive qualities of any equipment. Each of these key items requires, for basis and guidance, a detailed knowledge of the interrelations of equipment error and functional operation. Thus, error analysis fundamentally points the way to optimization of any desired quality or combination of qualities.

It is not difficult to understand how the development of error analysis techniques was retarded. But it is difficult to root out design habits grown from the lack of adequate procedures. One of the worst is that of specifying extreme component accuracy and manufacturing precision simply because an adequate error analysis, which would state where precision is and is not required, had not been performed as part of the system study preceding design. The results of such a philosophy in cost and waste manpower are obvious. The results in terms of equipment that exceeds requirements in unimportant respects are less obvious. But they are not less important in making instruments competitive in size, weight, and cost. Wasteful design habits can be cured—but only by requiring that, during design, detailed specifications be compared with actual requirements. These

FIG. 4A



Vector components $= \theta_1$ and θ_2

CHARACTERISTICS:

1. Extreme simplicity
2. Minimum equipment
3. Low accuracy
4. Frequency-dependent solution

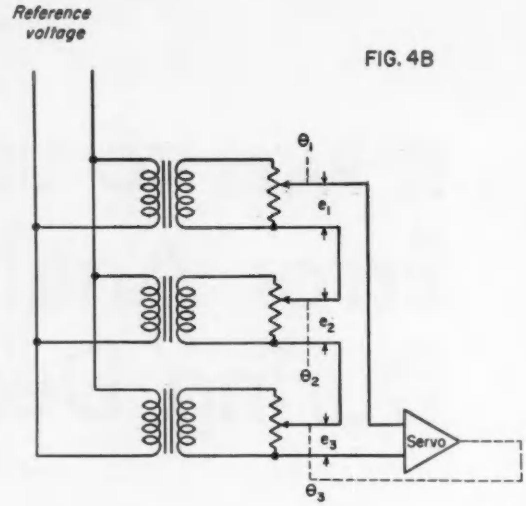
$e_1 = k\theta_1 \angle 0^\circ$

$e_2 = k\theta_2 \angle 90^\circ$

$e_3 = k\sqrt{\theta_1^2+\theta_2^2} \,\angle \tan^{-1}\frac{\theta_2}{\theta_1}$

$k\sqrt{\theta_1^2+\theta_2^2}$ = Required vector magnitude

FIG. 4B



CHARACTERISTICS:

1. Moderate simplicity
2. Servo required
3. Low accuracy
4. Good independence of frequency etc.

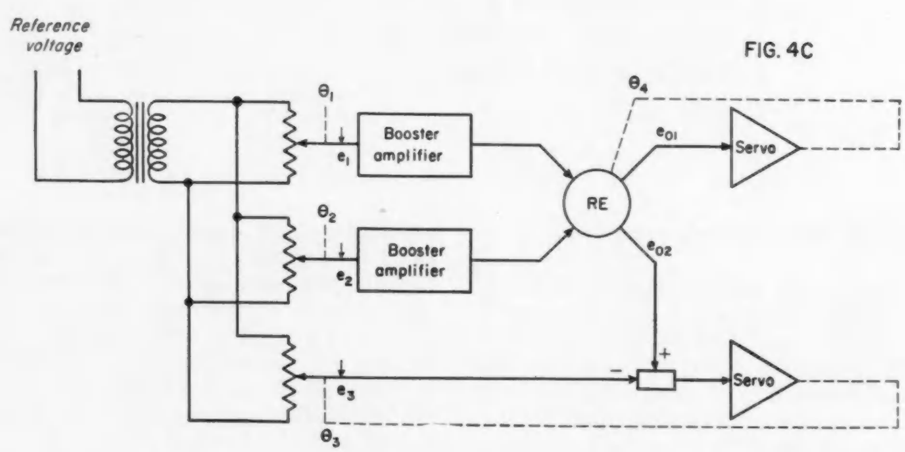
$e_1 = (k\theta_1)^2$

$e_2 = (k\theta_2)^2$

$e_3 = (k\theta_3)^2$

$e_3 = e_1 + e_2 = k^2(\theta_1^2+\theta_2^2) = k^2\theta_3^2$

FIG. 4C



$e_1 = k\theta_1$

$e_2 = k\theta_2$

$e_3 = k\theta_3$

CHARACTERISTICS

1. Moderate complexity
2. Two servos needed
3. High accuracy
4. Good independence of frequency

$e_{01} = e_1 \sin\theta_4 + e_2 \cos\theta_4 = \sqrt{e_1^2+e_2^2}\,\sin(\theta_4+\phi)$

$e_{02} = e_2 \sin\theta_4 - e_1 \cos\theta_4 = \sqrt{e_1^2+e_2^2}\,\cos(\theta_4-\phi)$

at solution $(\theta_4-\phi)=0$

and $e_{02} = \sqrt{e_1^2+e_2^2}$

$\phi = \theta_4 = \tan^{-1}\frac{\theta_2}{\theta_1}$

Three ways to compute a vector's magnitude for its orthogonal components. Each has different characteristics, and choice should be made only after considering required performance in the light of error analysis. FIG. 4

usually there is opportunity for considerable simplification. In an analysis where the objective is the control of functional relations to optimize some particular quality, the problems are more subtle.

To analyze a problem of this latter class, the basic relations in the real physical situation behind the analog instrumentation must be analyzed.

When a new problem is turned over to a system design group there is nothing that can be stated *a priori* about the functional relations that may exist between variables in the final analog instrumentation. There are, however, certain inherent relations between the variables of the problem. Using these inherent relations in combination with the best knowledge obtainable regarding input data sources, it is possible to compose a structure of inherent or situation data error. This structure then represents what might be called an ideal analog of the real problem and contains no instrumentation errors.

STEPS IN ERROR ANALYSIS

Step I: Compare with ideal analog

Figure 3 shows the steps for deriving an analog system instrumentation using error analysis to produce an optimum design. A comparison of the ideal analog with the requirements for the computer or control system being designed then yields the errors which may be allotted to instrumentation. Thus the first step in the allocation of error has been made. One objective of system design is to utilize the full amount of allowable error with due regard for safety factor. This is the only way that economical design can be realized. It relies heavily on the accuracy of initial requirements. Any doubt about the validity of these requirements must be settled before proceeding.

As previously stated, the use of error analysis in design cannot supplant thorough understanding of analog equipment. In the procedure being outlined, error analysis and system study go hand-in-hand in developing a system configuration.

The study to derive the ideal analog draws on the nature of initial data sources and the statement of the problem. It defines the absolute limits of quantities like the accuracy possible in the system, the order of derivatives of data that is separable from data error and noise, minimum solution time, and other limitations inherent in the problem situation. An estimate of the complexity of instrumentation can be drawn from the inherent complexity of the problem. A check on the validity of the system specifications can be made by examination of the problem and the nature of data sources.

Step 2: Derive the mathematical model

The next step in the process is derivation of the possible mathematical solutions to the problem. At this point ingenuity and imagination are primarily important; procedure is secondary. The result of this study is a mathematical model of the ideal analog. Analysis of the mathematical models makes possible separation of data source errors into static and dynamic ideal errors and into random and systematic errors. At this stage the error structure of the final design begins to appear, and from the mathematical model it is possible to make error allowances to sections of computation.

Step 3: Choose best instrumentation

Working from the mathematical models of the ideal analog, corresponding schematic instrumentations are devised. These must come from a knowledge of instrumentation techniques, and when complete, constitute the field from which the final instrumentation is selected. In this phase the balance of requirement against instrumentation shapes the design to match the qualities to be optimized. An example illustrating the selectivity possible at this stage is given in Figure 4.

The requirement for the example is computation of the magnitude of a vector, given the magnitude of two orthogonal components. Three possible instrumentations are shown, each with different characteristics. Detailed analysis of these three devices is not given here, but a summary of characteristics is included. From such characteristics an instrumentation compatible with requirements and optimization objectives is selected.

Step 4: Subdivide and analyze

Having outlined the possible instrumentations and chosen unit solutions compatible with overall objectives, the error allowances previously allocated to sections of computation are broken down into component allowances by a repetition of the procedure for each section. In this operation the section error allowances replace the original data source errors. The result is a functionally complete instrumentation with tolerances assigned by error allocation.

Final step: Add them up

The final step in the total error study must be an error analysis of the first kind outlined; that is, a systematic summation of errors from component errors using equipment functional relations.

Elements of the procedure outlined above are in constant use in analog system design. It has been found, however, that without a systematic approach, which includes all of the steps listed in one form or another, the results of the very considerable work are diffused and lost. Error analysis is valuable for two reasons. It forces the systems engineer to consider the importance of each quantity he specifies. And the detailed records that he must keep form a coherent, verifiable statement of the capabilities and limitations of a particular design. The method outlined has been used with variations on a number of systems. Even though it is cumbersome and lengthy, the results have more than justified the effort.

can be found by systematic error analysis.

Besides the importance of error study as a design tool, a statement of individual and combined errors in a system is invaluable in other ways. It is a guide in evolving test documents, manufacturing standards, trouble shooting and maintenance procedures. It gives an authoritative grasp of needed and potential performance.

Analysis of errors in a complex analog computer is not simple. Although much of the work involved is routine, its direction demands not only the specialized background of error-study and statistic-study techniques but also understanding of analog devices.

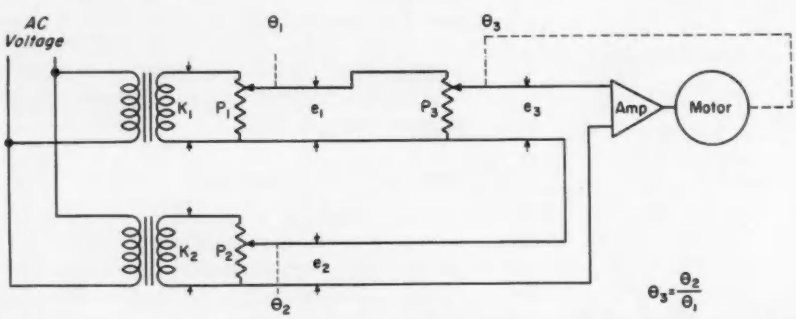
Error analysis may be a simple examination of static errors in equipment already designed. Or it may be the derivation and allocation of errors, combining related and random errors under the influence of dynamic effects, in several possible instrumentations for a new problem—which is not simple.

FUNDAMENTALS OF ERROR ANALYSIS

In examination of a completed design, certain rules may apply. For example, in the case of errors not related to each other, the error of a sum of a number of quantities can be expressed as the square root of the sum of the individual errors. This statement holds generally, but is theoretically sound only when individual errors have no preferential set, or bias, within their own tolerances. Where errors are related, error build-up is generally determined by that relation.

An example of beneficial related errors is the variation of reference voltages in analog computers.

Figure 1 is a servo divider. Voltage e_1 is a variable that depends on the angle θ_1 of potentiometer P_1. K_1 is a reference voltage exciting P_1 and has a nominal value K_{n1} and an error, or deviation from nominal, amounting to a. Voltage e_1 can be expressed as $e_1 = K_1C_1\theta_1$, where C_1 is a potentiometer scale factor.



Simple servo divider illustrates how quickly error analysis mushrooms into lots of algebra (see discussion in text). FIG. 1

FORMIDABLE ANALYSIS PROBLEMS . . .

(A) Exact expression of the error E in the product $R \cos\theta \cos\phi = f(R, \theta, \phi)$ is:

$$
\begin{aligned}
E = {} & R\cos\theta\cos\phi - R\cos\theta\cos\Delta\theta\cos\phi\cos\Delta\phi \\
& + R\cos\theta\cos\Delta\theta\sin\phi\sin\Delta\phi + R\sin\theta\sin\Delta\theta\cos\phi\cos\Delta\phi \\
& - R\sin\theta\sin\Delta\theta\sin\phi\sin\Delta\phi - \Delta R\cos\theta\cos\Delta\theta\cos\phi\cos\Delta\phi \\
& + \Delta R\cos\theta\cos\Delta\theta\sin\phi\sin\Delta\phi + \Delta R\sin\theta\sin\Delta\theta\cos\phi\cos\Delta\phi \\
& + \Delta R\sin\theta\sin\Delta\theta\sin\phi\sin\Delta\phi
\end{aligned}
$$

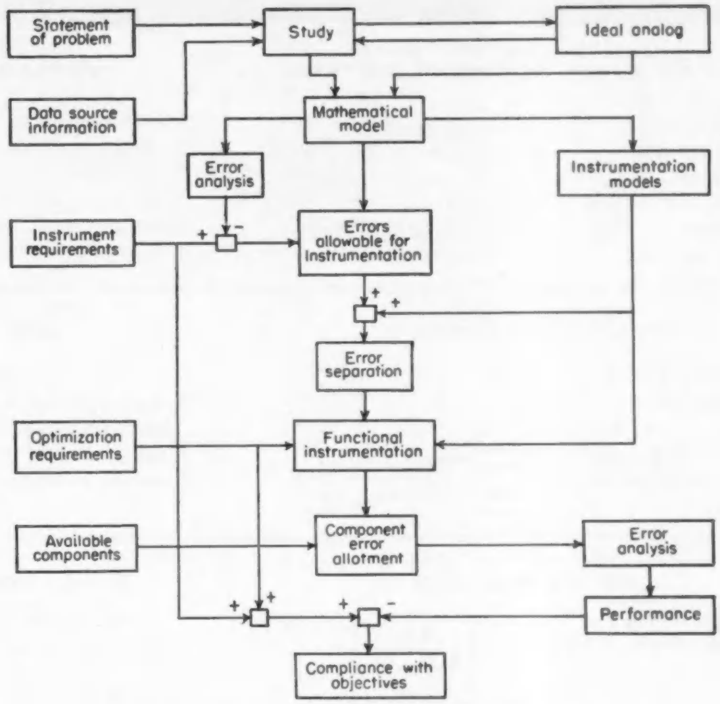
. . . CAN OFTEN BE SIMPLIFIED

(B) Assuming: the cosine of Δ angles = 1, the product of two or more Δ's or sine Δ's is negligible,

$$
\begin{aligned}
E = {} & R\cos\theta\sin\phi\sin\Delta\phi + R\cos\phi\sin\theta\sin\Delta\theta \\
& + \Delta R\cos\theta\cos\phi
\end{aligned}
$$

Even simple relations get involved (A), but there is hope (B). FIG. 2

THE STEPS IN ERROR ANALYSIS



A proven procedure for error analysis during design. FIG. 3

Similar relations apply to P_2 and P_3, except that P_3 is excited by the voltage e_1. The difference between voltages e_3 and e_2 is amplified to drive the motor until $e_3 = e_2$. Then, since $e_3 = C_3\theta_3 e_1$,

$$K_1C_1\theta_1C_3\theta_3 = K_2C_2\theta_2$$

$$\theta_3 = \frac{K_2C_2\theta_2}{K_1C_1C_3\theta_1} = \frac{K_{n2}C_2\theta_2}{K_{n1}C_1C_3\theta_1}$$

which expresses the division of θ_2 by θ_1, with the condition of no reference voltage errors. If the reference voltages vary, however, the expression becomes

$$(K_{n1} + a)C_1\theta_1C_3\theta_3 = (K_{n2} + b)C_2\theta_2$$

and the error is

$$E = \frac{K_{n2}C_2\theta_2}{K_{n1}C_1\theta_1C_3} - \frac{(K_{n2} + b)C_2\theta_2}{(K_{n1} + a)C_1\theta_1C_3}$$

$$= \frac{C_2\theta_2}{C_1\theta_1C_3}\left(\frac{K_{n2}}{K_{n1}} - \frac{K_{n2} + b}{K_{n1} + a}\right)$$

For the divider to be independent of reference voltage variation, E must be zero, and the following relations hold true:

$$\frac{K_{n2}}{K_{n1}} - \frac{K_{n2} + b}{K_{n1} + a} = 0$$

$$K_{n1}K_{n2} - K_{n1}K_{n2} + K_{n2}a - K_{n1}b = 0$$

$$K_{n2}a = K_{n1}b$$

$$\frac{K_{n1}}{K_{n2}} = \frac{a}{b}$$

The last equation states that if variations in reference voltages remain in the ratio of the nominal values of these voltages, no error results. This is usually done by scaling all reference voltages from the same source.

Error analysis is not easy

The principal purpose of this example, besides the interesting result, was to show how quickly the complexity of statements of errors builds up even in a simple case where only two points were error sources.

For a more drastic demonstration, an exact expression of the error of a simple relation such as $R \cos\theta \cos\phi = f(R, \theta, \phi)$ is quite formidable (see Figure 2A) and illustrates the need for valid simplifying assumptions and systematic handling of an error structure in analog work. The expression simplifies appreciably if it is assumed that the cosine of Δ angles equals 1, and that the product of two or more Δ's or sin Δ's is negligibly small (Figure 2B). These assumptions are valid for small error angles.

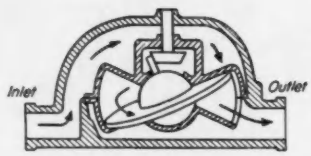
This second example also illustrates another rule for calculating error build-up: The explicit error of a product of terms is equal to the difference between the product if no error existed and the product of the terms with an expression of individual error.

Thus, although an error analysis in which the relation between variables is stated is often very complex, the approaches are still straight-forward, and

VOLUMETRIC FLOWMETER CLASSIFICATIONS TABLE I

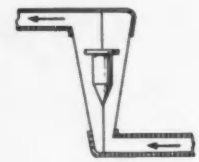
POSITIVE DISPLACEMENT METERS

1. Totalizes flow directly
2. Variable pressure drop
3. Wide flow range
4. High accuracy over flow range
5. Functions mechanically; size restricted by size of parts



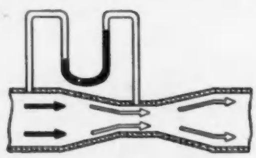
VARIABLE-AREA METERS

1. Constant pressure drop
2. Indicates rate of flow
3. Must be time integrated for quantity totalization
4. Accurate over full range
5. One moving part in flow element



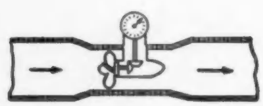
VENTURI METERS

1. Pressure differential device
2. Indicates rate of flow
3. Must be time integrated for quantity totalization
4. Nonmechanical flow element
5. High capacity



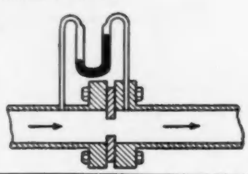
VELOCITY METERS

1. Totalizes flow directly; infers quantity by sensing velocity
2. Low pressure drop
3. Functions mechanically



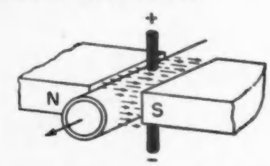
ORIFICE METERS

1. Pressure differential device
2. Indicates rate of flow
3. Must be time integrated for quantity totalization
4. Nonmechanical flow element
5. Reduced accuracy at low rates



ELECTROMAGNETIC METERS

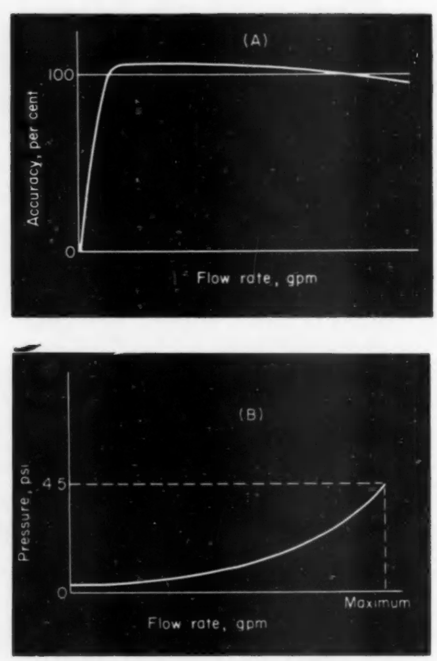
1. Indicates flow rate
2. No pressure drop
3. No mechanical parts
4. No viscosity or density effects
5. Linear response
6. Liquid must be conductive



WHAT YOU SHOULD KNOW ABOUT

Positive Displacement Meters

RUSSELL W. HENKE, Badger Meter Mfg. Co.

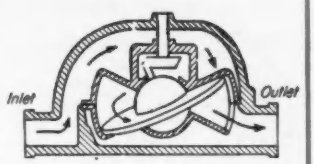


Accuracy and pressure drop through meter plotted against rate of flow for a typical nutating disc positive displacement meter. FIG. 1

THESE ARE THE POSITIVE DISPLACEMENT METERS TABLE II

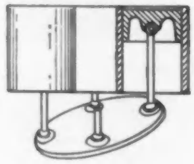
NUTATING DISC

1. Most widely used
2. Accurate within plus or minus 1.5 per cent
3. Simple, low cost and rugged
4. Relatively low pressure drop



RECIPROCATING PISTON

1. Most accurate
2. Slightly higher pressure drop than others
3. Most expensive

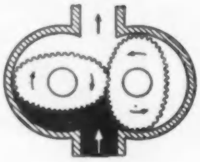


OSCILLATING PISTON

1. Sensitive at low flows

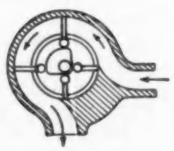
OVAL GEAR

1. Accurate within plus or minus 0.5 per cent
2. Low pressure drop
3. Simple construction, low cost
4. Low maintenance



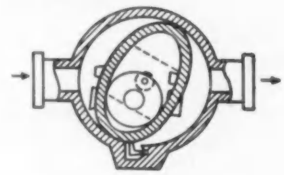
VANE TYPE

1. Relatively low pressure drop
2. Accurate



ROTARY PISTON

1. Early development; not available now



Though not glamorous, they're the backbone of many control systems. Here's

WHAT THEY DO . . .

▸ The positive displacement meter is a flow sensing instrument. It responds to variations in flow rate and delivers a corresponding mechanical signal; the rotation of its spindle.

▸ This mechanical output signal can be coupled to a variety of devices.

These devices fall into several classes.

a. Those that totalize and register quantity of fluid through the meter.

b. Those that control some other piece of equipment.

c. Those that are of themselves the control or the process.

. . . AND WHERE THEY APPLY

▸ Where a wide range of flow is encountered.

▸ Where a nominally linear response to flow rate variation is required.

▸ Where mechanical actuation is desirable.

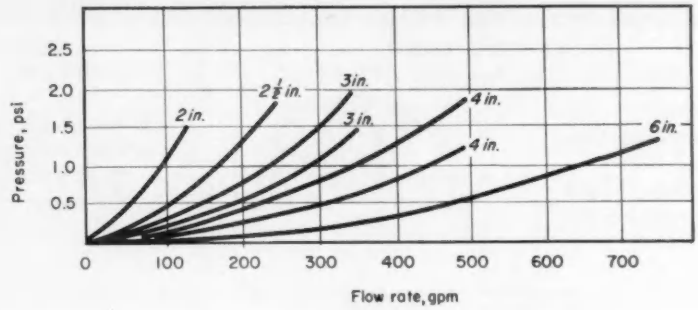
Many types of flow metering equipment are commercially available. The standard classes of volumetric flow measuring devices are listed in Table I. These units can measure either the total volume of liquid that flows through them in a given time, or the rate of volumetric flow. Other varieties of meters are available to measure the mass rate flow of a liquid.

Each type of volumetric metering device has specific characteristics that recommend it for certain applications. For example, the venturi, orifice, area, and electromagnetic meters are inherently suited for measuring flow rates. If a quantitative or volumetric indication is needed, these classes of instruments require time-integrating auxiliaries to accomplish the totalization. On the other hand, positive displacement meters are inherently quantitative or volumetric instruments and are not suited to measuring flow rates.

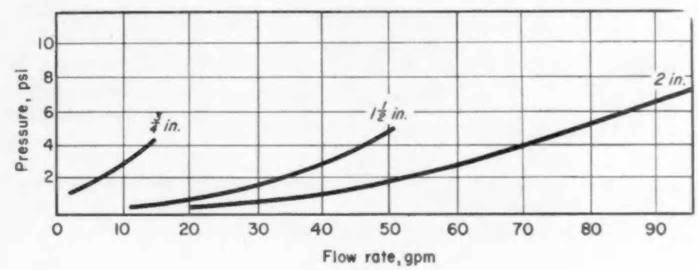
The velocity-type meters, while they depend on velocity effects, are used to register quantities of liquid passed, rather than flow rates. This class of equipment is not so accurate in the low flow ranges as are the positive displacement meters.

Positive Displacement Meters

The available types of positive displacement meters



Pressure drop versus flow rate curves for various sizes of vane-type positive displacement meters. FIG. 2



Pressure drop versus flow rate curves for various sizes of reciprocating piston meters. FIG. 3

are shown in Table II. The nutating disc meter has widest use. Simplicity of construction, sturdiness, long life and relatively high accuracy are responsible.

Figure 1(A) shows a typical accuracy curve for a nutating disc meter. Note that the error over the sensible flow range of 0.5 gpm to the maximum rated capacity of about 40 gpm is within plus or minus 1.5 per cent. A typical pressure-loss curve for the same meter, Figure 1(B), indicates a pressure loss of about 4.5 psi at the maximum flow rate.

These curves point out two important characteristics of positive displacement meters: high accuracy of volumetric registration and relatively low pressure drops through the meter over extremely wide flow ranges.

The oscillating piston meter is the next most popular type of positive displacement meter. The characteristics of this meter parallel closely those of the nutating disc. But the oscillating piston has greater sensitivity than the disc in the lower flow ranges. This advantage is offset to some extent by the more critical machining requirements and increased sensitivity to damage or fouling by foreign matter.

The rotary piston meter was one of the first types of positive displacement meters and has been largely replaced by the other types.

Vane-type meters are widely used in the fields that most need their high capacity and can best stand their higher cost. Figure 2 shows pressure-drop curves for various sizes of rotary-vane-type meters. Accuracy can be held high enough to meet U. S. Bureau of Standards requirements.

Reciprocating piston meters are the most accurate of all the positive displacement meters and are also the most expensive. They are used in metering for excise tax purposes, where high accuracy is essential. Figure 3 shows a typical pressure-flow curve for this type of meter.

How to Use These Meters

In addition to the basic units, there are many accessory devices used in conjunction with positive displacement meters. These may register the total flow through the meter, permit a preset quantity of liquid to flow through the meter, or control some other flow in accordance with the flow through the meter. Table III surveys some of the commercially available meter accessories.

To the engineer, control can mean the pacing of a process by means of instrumentation that senses the instantaneous state of a process and uses this information to maintain the required conditions. To management, control means planning; cost control and production planning and scheduling. For management to exercise this control, it must have data on which to base its decisions. Metering has its place in both facets of the control field.

Data Gathering Functions

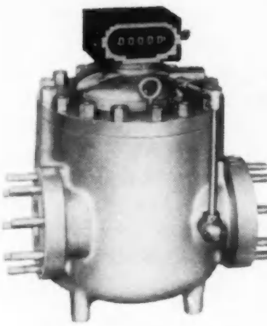
Positive displacement meters equipped with registers are used for data gathering purposes. These data can be used to:

- account for total product manufactured

HOW POSITIVE DISPLACEMENT METERS ARE INSTRUMENTED

TABLE III

STRAIGHT-READING REGISTERS



TOTALIZER

Indicates total quantity delivered. Has reset to zero so individual deliveries can be totalized.

A. O. Smith Corp., Meter Div.

VISIBLE REGISTER

Used by most meter manufacturers. Totalizes quantity delivered. Has zero reset.

Veeder-Root Inc.

TICKET PRINTER

Totalizes quantity delivered and also prints ticket or card with record of quantity.

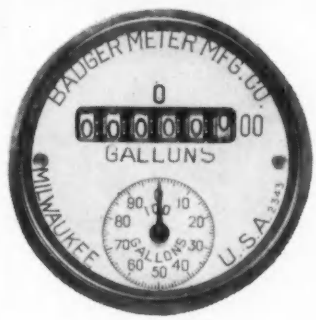
Veeder-Root Inc.

WATER-METER REGISTERS

CIRCULAR

Standard water-meter register. Mounted horizontally with no reset to zero, it totalizes flow on five small dials.

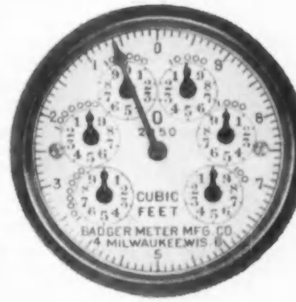
Badger Meter Mfg. Co.



STRAIGHT READER

Standard water-meter register. Totalizes on straight reading register odometer. Mounts horizontally and has circular test dial.

Badger Meter Mfg. Co.

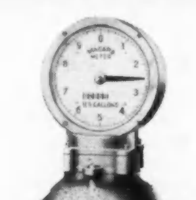


CIRCULAR SWEEP TEST

Standard water-meter register. Totalizes on six dials. Mounts horizontally, has sweep hand test circle and no zero reset.

Badger Meter Mfg. Co.

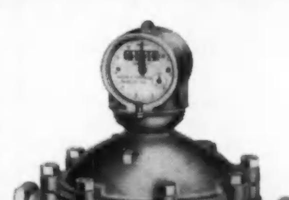
CIRCULAR REGISTERS



VERTICAL DIAL

Available in diameters from four to sixteen inches with one or two pointers. Has reset to zero. Dials can be calibrated in any standard unit of volume.

Buffalo Meter Co.



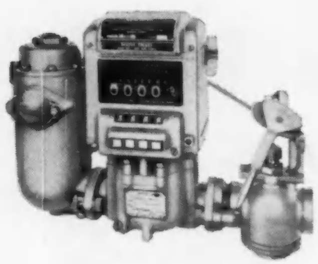
ELECTRIC ALARM

Arranged to deliver an electrical impulse after a given volume has passed through the meter. Operates either singly or repetively.

Badger Meter Mfg. Co.

TABLE III *continued*

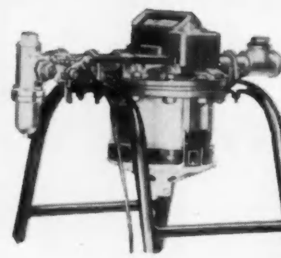
CONTROL INSTRUMENTATION



PREDETERMINING REGISTER

Quantity to be measured is set on register and valve is opened. When predetermined quantity has passed, the valve is automatically closed.

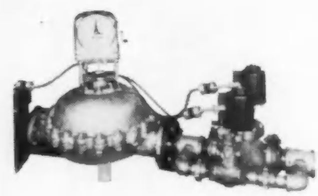
Bowser, Inc.



PACKAGING UNITS

Unit can be preset to deliver quantities that will fill standard containers. For example, 25 or 55 gal drums, or 5 or 10 gal cans.

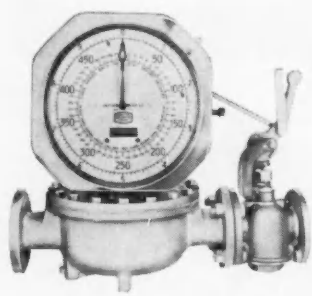
Neptune Meter Co.



RECYCLING CONTROL

Automatically recycles after delivering a predetermined quantity and reinitiates the cycle without manual starting.

Hetherington and Berner, Inc.



BATCHING CONTROL

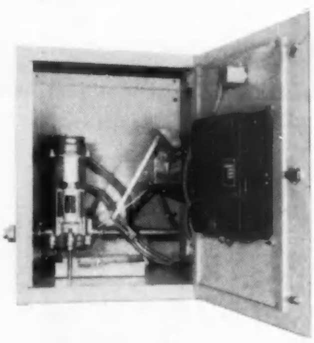
Used to control batching operations. Quantity is set by manually rotating pointer. Subtracting type counter returns pointer to zero at which time valve closes automatically. Must be manually recycled.

Neptune Meter Co.

AUTOMATIC SAMPLER

Automatically extracts sample of main stream flow in proportion to flow rate. Used extensively in petroleum industries for sampling crudes and distillates.

A. O. Smith Corp., Meter Div.

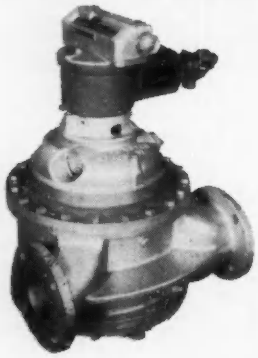


RATE OF FLOW INDICATOR

Meter driven generator delivers a voltage proportional to spindle speed. A galvanometer calibrated in gpm gives rate of flow.

The Hays Corp.

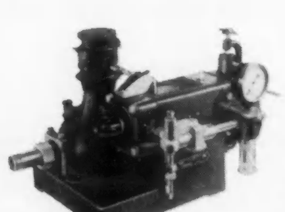
CHEMICAL FEED CONTROL



CHEMICAL PUMP CONTROL

Positive displacement meter controls the speed of a chemical feed pump so that delivery is proportional to main line flow.

B-I-F Industries, Inc.



CHEMICAL FEED DRIVE

Positive displacement meter controls pumping rate by mechanical interlock. Thus, it maintains proportionality to the flow through the meter.

Wallace & Tiernan Inc.

▶ account for constituents used in the manufacture of products
▶ account for waste of material
▶ check the delivery of raw materials
▶ check the delivery of finished products
▶ account for products delivered for billing.
▶ account for unit consumption in product manufactured.

This information can be collected in two ways, depending on the scope of the operation, on what level the data are collected, and for what purpose. For independent installations, any of the direct reading registers shown in Table III can be used. To obtain the data from these units, the operator must go to the spot where the meter is installed. This type of unit is particularly adapted to single installations, mobile units, or those in the vicinity of an operator's station.

The estimated cost of such an installation ranges from $30 to $1,500, depending on the size, type, and application of the meter. Error varies from 0.5 to 1.5 per cent depending on the type of meter. Available flow ranges vary from 0.25 to 26 gpm in one meter up to 5 to 3,000 or 4,000 gpm, depending again on the size and type of meter.

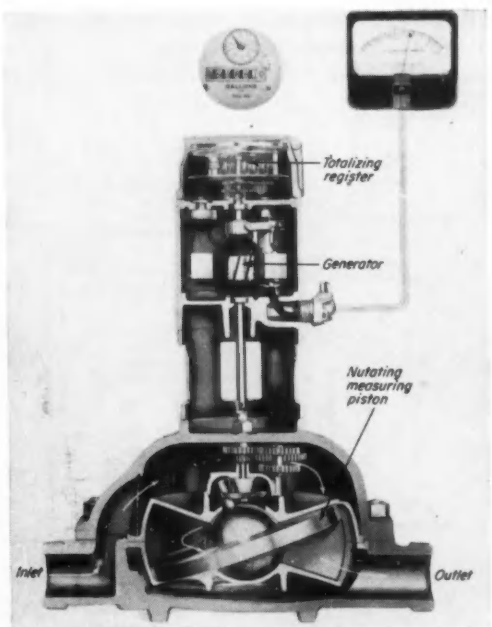
For large installations where the number of meters to be read or the distance between stations prohibits individual readings, the remote indicating unit shown in Figure 4 is advantageous. In this type of installation a transmitting head is mounted on the meter and the totalizing unit is located in a central control station. The cost of a single such installation would range from $150 to $3,000. Accuracy and available flow ranges are similar to those above.

Even with remote indicating registers it may be impractical to try to keep a record of all the meter registrations in a large installation by visual examination and manual recording of data. In these applications, recording mechanisms can be substituted for the registers, Figure 5. Not only is the operator relieved of the task of reading the meters, but a permanent record of the flow is available. The cost of such an installation ranges from $500 to $5,000 depending on the size and type of meter and the type and capacity of the recording equipment.

Process Control Functions

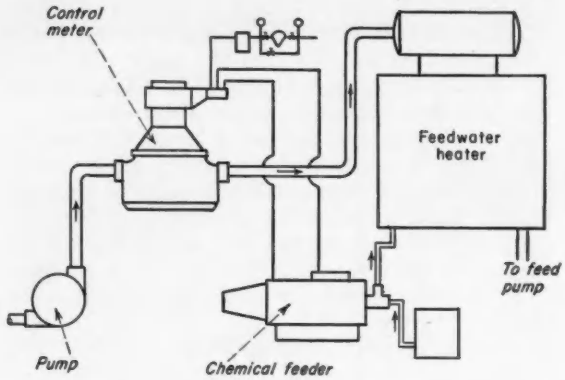
Positive displacement meters are used in process control applications when the volumetric flow of a liquid must be controlled. Typical applications are:

▶ Control of liquid added in batch mixing processes. For example, caustic dilution and fluoridation
▶ Water treatment
▶ pH control
▶ Automatic titration
▶ Injection of corrosion inhibitors
▶ Injection of vinsol resin in cement manufacture

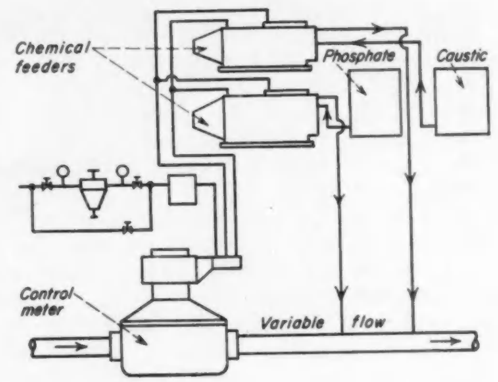


Typical remote indicating equipment used with positive displacement meter. Generator on meter shaft develops voltage proportional to rate of flow. The Hays Corp. FIG. 4

Typical recorder used with positive displacement meters. Rockwell Manufacturing Co. FIG. 5



Flow-responsive boiler feedwater system in which meter maintains correct proportion of treating agent to feedwater. B-I-F Industries, Inc. FIG. 6



Positive displacement meters are used to maintain the correct proportion of chemical treatment to water in many types of water softening systems. B-I-F Industries, Inc. FIG. 7

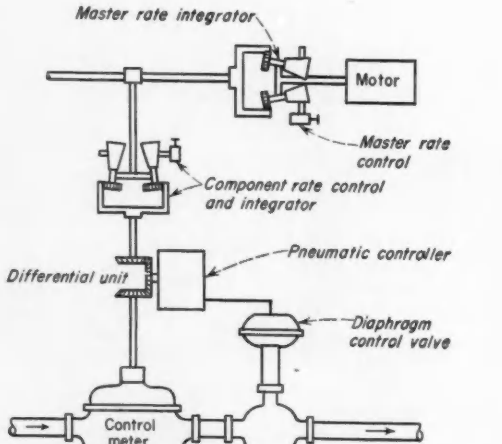
- ▶ Sizing injection
- ▶ Addition of wetting agents
- ▶ Hydrochlorination
- ▶ Catalyst injection
- ▶ Proportional blending operations
- ▶ Packaging operations.

The two meter-controlled systems described in the following paragraphs are typical examples showing the application of positive displacement meters in chemical feeding equipment.

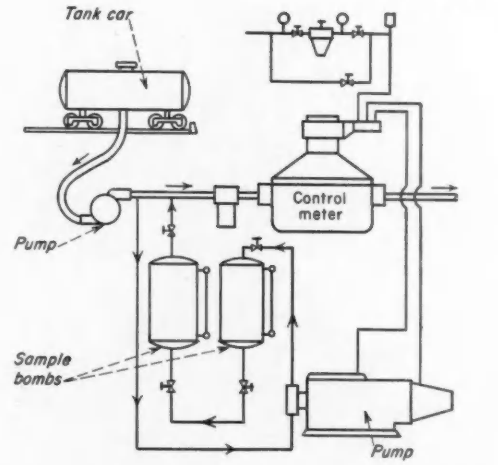
In these applications it is necessary to feed or blend one or two liquids in definite proportion to another liquid. The sensing device on the meters shown in Figures 6 and 7 is a pneumatic pilot valve that alternately applies high and low pressure across the driving piston of the chemical feeder pump. The frequency of alternation is directly proportional to the revolutions of the control meter's spindle. Thus, as the flow rate in the metered line varies, the chemical feeder is speeded up or slowed down, thus maintaining constant ratio.

Figure 6 shows a positive displacement meter as the control instrument in a flow-responsible boiler feedwater system. The signal from the transmitting head actuates the chemical pump to maintain the ratio of treating agent to feedwater at a predetermined value. The meter equipment only for such an installation ranges in cost from \$150 to \$1,000, depending on the size and materials of construction of the meter.

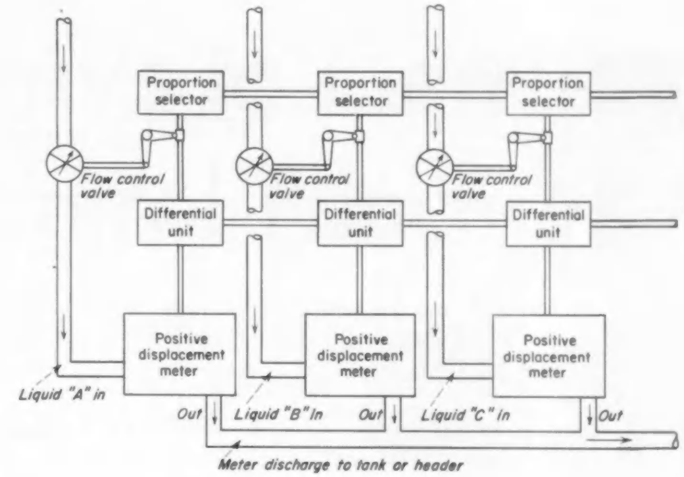
Positive displacement meters are often used to control the proportioning of water softening chemicals in the "lime soda" or "hot process phosphate"

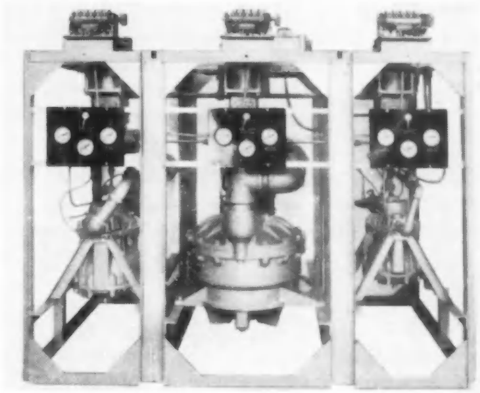


Total flow rate control and blending system. One master control, stacked with several component control units, permits controlled blending. FIG. 8

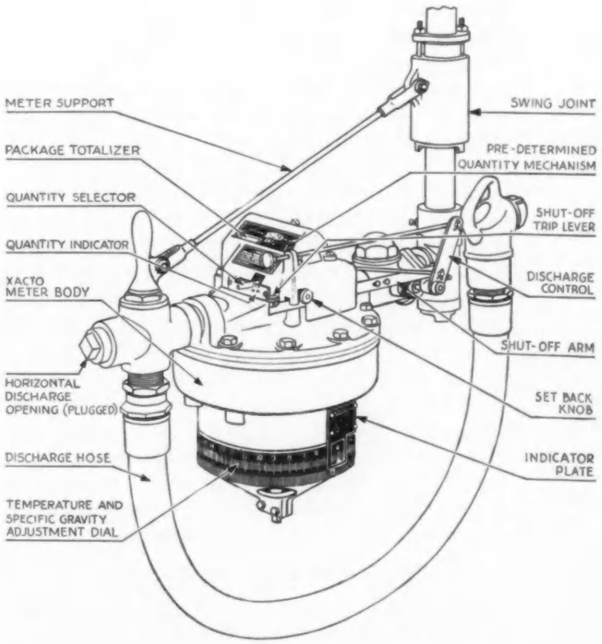


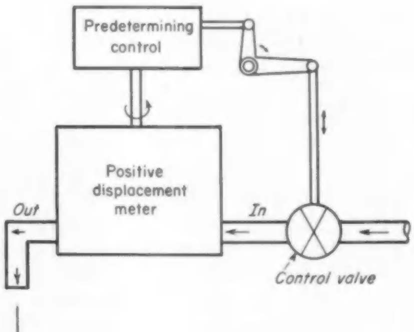
System for extracting a sample proportional to total flow in delivery or production line. FIG. 9. Figures 8 and 9 B-I-F Industries, Inc.



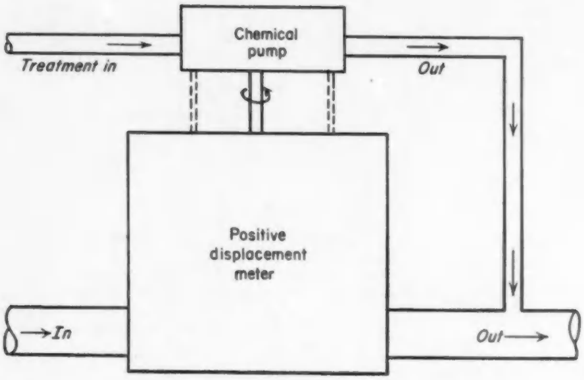


Photograph and schematic diagram of commercially available automatic blending system. Cost per bank runs about the same as the system shown in Figure 8. Bowser, Inc. FIG. 10





Packing equipment used for filling containers with a predetermined quantity of liquid. Bowser, Inc. FIG. 11



Photograph and schematic of integral chemical proportioning unit. The meter drives the pump directly. FIG. 12

processes. Meters are similarly applied to control the "hot zeolite" process. A typical installation is shown in Figure 7. The water-softening chemicals are introduced by the chemical feeders, and the meter controls the rate of feeding to maintain a predetermined ratio of treatment to water.

When a positive displacement meter is used in flow control instrumentation, Figure 8, the spindle is connected to one side of a differential, which is driven from the other side by a component rate control and integrator. If the meter and component integrator speeds are equal, the differential connection to the pneumatic controller stands still and the valve position remains fixed. If the speeds differ, the valve varies the flow in the proper direction to bring meter spindle speed back into correspondence with integrator speed. A master rate integrator and rate control maintains overall control of many units.

This type of control can be stacked for blending several liquids in predetermined proportions—for example, blending lubricating oils. In this application, varying the setting of the master rate control adjusts the rate of flow of the final product, while the setting of the component control devices adjusts the proportion of the various constituents that make up the final product. The cost of a single bank of this equipment will range from $1,000 to $4,000.

Many continuous-process operations require the sampling of liquids. This might be done for quality control checks on production processes or for inspecting incoming liquid materials to make sure that they meet specifications. A typical system used for automatic, flow-responsive sampling is shown in Figure 9.

In this installation, the positive displacement meter controls a pumping unit that extracts sample material from the process or delivery line and pumps it into sample bombs. The amount of the sample is always proportional to the total flow. Meter equipment cost varies from $150 to $1,000.

Figure 10 shows a typical commercially available automatic blending system. This is similar to the system shown in Figure 8. Each meter, differential, selector and related equipment is packaged as an integral unit. Again, large blending systems can be built up by stacking these individual units to handle as many liquids as desired.

Equipment is available for specialized packing applications, such as barrel and can filling operations, where it is necessary to control the exact amount of liquid dispensed. Unit in Figure 11 is commercially available. Flow is started by opening the valve. When a predetermined quantity of liquid has passed through the meter (as set on the preselecting meter register) the control valve is automatically closed. Equipment cost ranges from $300 to $1,000.

One class of chemical proportioning units includes the meter and chemical feeder as a integral unit. These differ physically from the previously discussed chemical proportioning equipments where the meters were used as flow-sensing auxiliaries.

In the integral units shown in Figure 12, a pump is mounted on the head of the meter and is driven by the meter spindle. Thus the unit is inherently flow-responsive. And once a proportion is established, it will be maintained over the entire flow range. Since the pump is driven by the meter, no electric motor is required. Cost is $150 to $300.

SELECTED REFERENCE

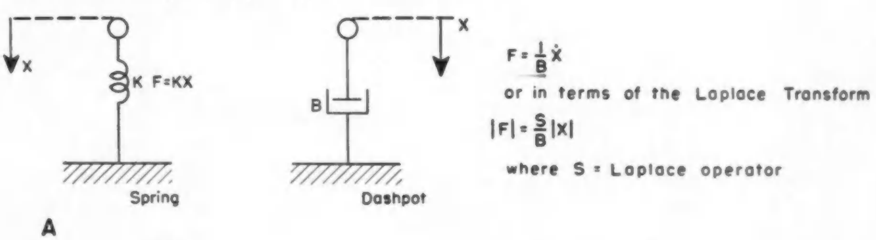
"PROPORTIONING LIQUIDS AUTOMATICALLY", Lawrence Lowy, *Control Engineering*, September 1954.

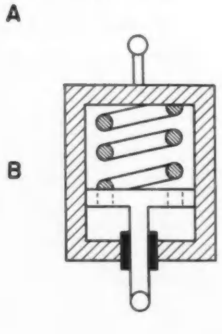
14 Ways to Generate Control Functions Mechanically

THE GIST: Often the performance of a closed loop system can be improved by placing the proper control function generator or stabilizing network in the loop. For example, any time lag between a change in input and the application of a correcting force to the output tends to cause instability. With a varying input, this delay can cause the correction to be applied at the wrong time or in the wrong direction, either of which can result in an oscillatory response of the output. Two solutions are possible: either reduce the system gain or compensate for the time lag. Reducing the gain reduces accuracy and speed of response. But a function generator that will predict probable error can stabilize the system without sacrificing performance.

Many types of function generators are available depending on the system requirements and on the control medium. Thus pneumatic and electrical function generators were covered in "Generating Control Functions Pneumatically" and "AC Stabilizing Networks," both in the September 1954 issue of CONTROL ENGINEERING. This article gives the schematic diagram, transfer function, and magnitude ratio versus frequency for fourteen different mechanical networks.

(A) The two basic elements of mechanical function generators.
(B) Parallel dashpot and spring as one unit. FIG. 1





JOHN E. GIBSON, School of Engineering, Yale University

When a system has mechanical linkages it is convenient to design the controller or function generator with mechanical elements. For the networks shown in the accompanying table, only two kinds of elements are used. First a spring with stiffness K, as defined by the spring's reaction force F and change in length X. And second a dashpot that gives viscous damping, where the reaction force is proportional to velocity. These are shown in Figure 1(A). These

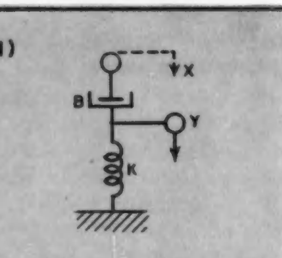
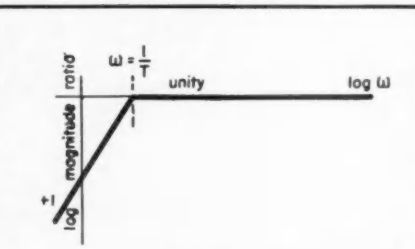
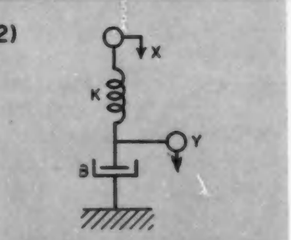
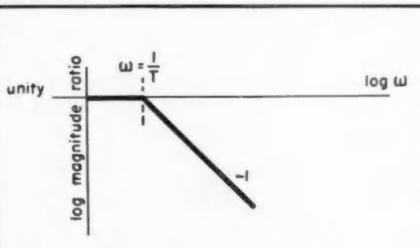
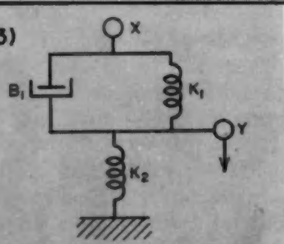
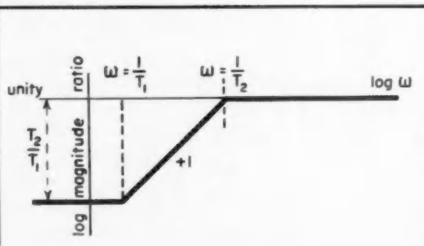
two elements may be in their translatory form or in their rotational form depending on the application. Where a dashpot and spring are used in parallel, it is often possible to include both elements within the dashpot case, thus simplifying the unit, Figure 1 (B).

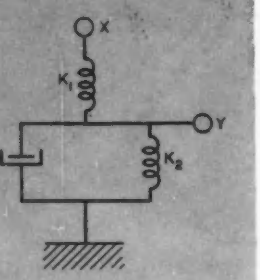
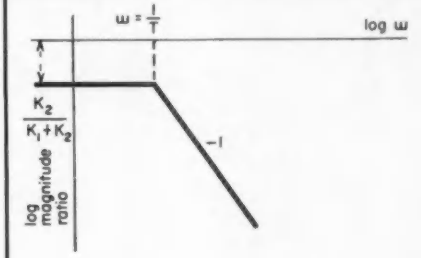
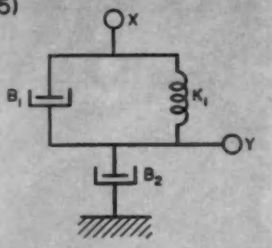
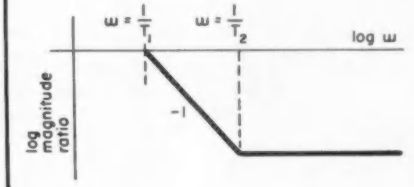
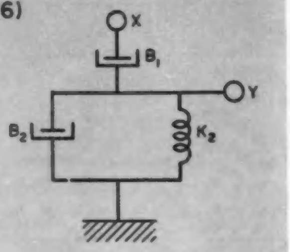
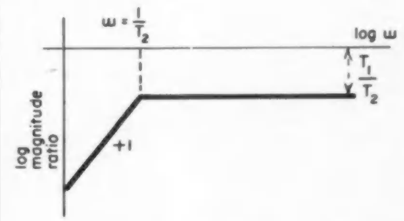
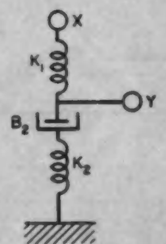
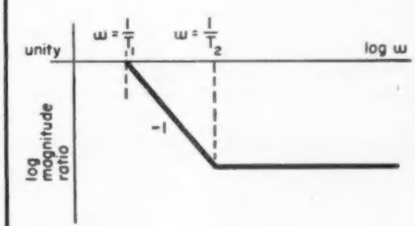
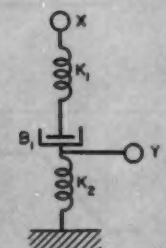
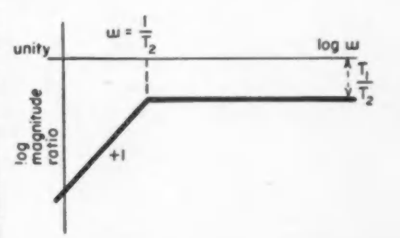
Several precautions must be taken when installing a controller in a system. The device that senses the output of the controller must not load the controller. For practical designs, the force required to move the sensing or pickoff device should be not more than one-tenth the force required to move the output element of the controller. Also, if two controllers are placed in series, the second stage must not load the first. Since this may require a wide range of dashpot and spring constants, it may be advisable to place the two stages in different portions of the loop.

Note that several of the configurations in the following table yield the same transfer function; for example, three and nine, four and ten, five and seven, six and eight, and eleven and twelve. In each pair, one of the connections is in series and the other in parallel. The choice of configuration depends on the particular system being stabilized. It is sometimes possible to use one or more of the elements that make up the original system as part of the controller. Several choices of configuration increase this possibility.

A common nomenclature for these control functions is based on their application in certain conventional systems. A transfer function that is flat (zero slope) and below unity in called a proportional control function, since presumably only the attenuated signal is fed back. A transfer function that gives a curve with a slope of plus one is called a rate, or derivative, function, since in the region of plus-one slope the output is the derivative of the input. Number three shows an example of proportion plus rate. This is also called a lead network, since the output leads the input in the steady state. A function with a minus one slope is called reset or integral control, since in the region of the minus-one slope the output is the integral of the input. Number five shows proportional plus reset. This is also called a lag network, since the output lags the input. Number fourteen is an example of proportional plus reset plus rate or a lag-lead network.

14 MECHANICAL FUNCTION GENERATORS

Schematic Diagram	Transfer Function (In the steady state $s = j\omega$)	Log magnitude ratio vs. log frequency
(1) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{TS}{1+TS}$ $T \triangleq \frac{1}{KB}$	
(2) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{1}{1+TS}$ $T \triangleq \frac{1}{KB}$	
(3) 	$\left\lvert\frac{Y}{X}\right\rvert = \left(\frac{T_2}{T_1}\right)\frac{(1+T_1 S)}{(1+T_2 S)}$ $T_1 \triangleq \frac{1}{K_1 B_1},\ T_2 \triangleq \frac{1}{B_1(K_1+K_2)}$	

Schematic Diagram	Transfer Function	Log magnitude ratio vs. log frequency
(4) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{K_1}{K_1+K_2}\left(\frac{1}{1+TS}\right)$ $T \triangleq \frac{1}{B_2(K_1+K_2)}$	
(5) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{(1+T_2S)}{(1+T_1S)}$ $T_1 \triangleq \frac{B_1+B_2}{B_1B_2K_1}$, $T_2 \triangleq \frac{1}{B_1K_1}$	
(6) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{T_1S}{(1+T_2S)}$ $T_1 \triangleq \frac{1}{K_2B_1}$, $T_2 \triangleq \frac{B_1+B_2}{B_1B_2K_2}$	
(7) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{(1+T_2S)}{(1+T_1S)}$ $T_1 \triangleq \frac{K_1+K_2}{B_2K_1K_2}$, $T_2 \triangleq \frac{1}{B_2K_2}$	
(8) 	$\left\lvert\frac{Y}{X}\right\rvert = \frac{T_1S}{(1+T_2S)}$ $T_1 \triangleq \frac{1}{K_2B_1}$, $T_2 \triangleq \frac{K_1+K_2}{B_1K_1K_2}$	

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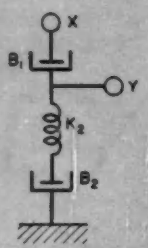
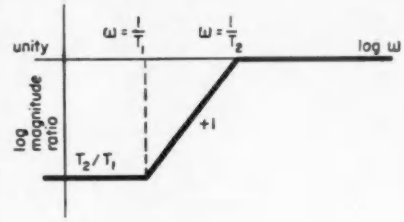

</td>
<td>$\left|\frac{Y}{X}\right| = \left(\frac{T_2}{T_1}\right) \frac{(1+T_1S)}{(1+T_2S)}$

$T_1 \triangleq \frac{1}{K_2B_2}, \; T \triangleq \frac{1}{K_2(B_1+B_2)}$</td>
<td>
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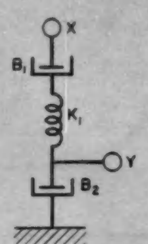
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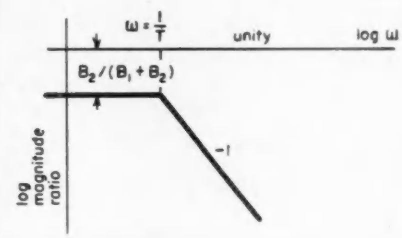
<td>$\left|\frac{Y}{X}\right| = \frac{B_2}{B_1+B_2} \; \frac{1}{1+TS}$

$T \triangleq \frac{1}{K_1(B_1+B_2)}$</td>
<td>
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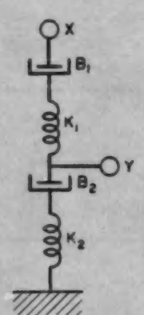
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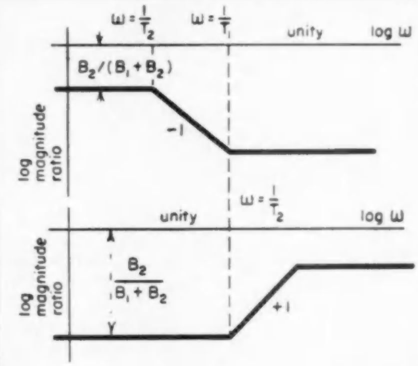
<td>$\left|\frac{Y}{X}\right| = \frac{B_2}{B_1+B_2} \; \frac{(1+T_1S)}{(1+T_2S)}$

$T_1 \triangleq \frac{1}{B_2K_2}, \; T_2 \triangleq \frac{K_1+K_2}{(K_1K_2)(B_1+B_2)}$

See note 1</td>
<td>
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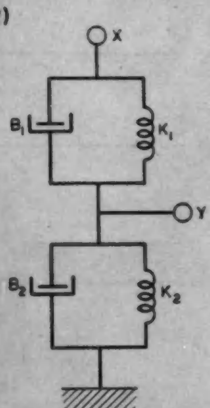
<td>(12)

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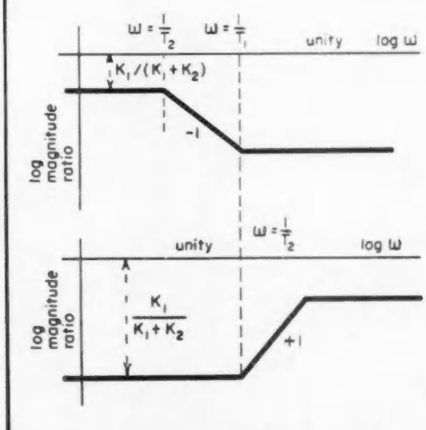
<td>$\left|\frac{Y}{X}\right| = \frac{K_1}{K_1+K_2} \; \frac{(1+T_1S)}{(1+T_2S)}$

$T_1 \triangleq \frac{1}{K_1B_1}, \; T_2 \triangleq \frac{B_1+B_2}{B_1B_2(K_1+K_2)}$

See note 1</td>
<td>
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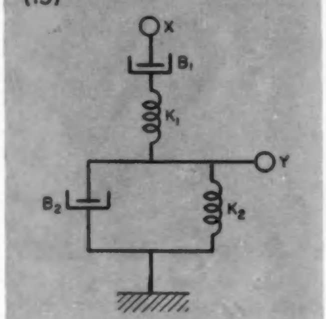
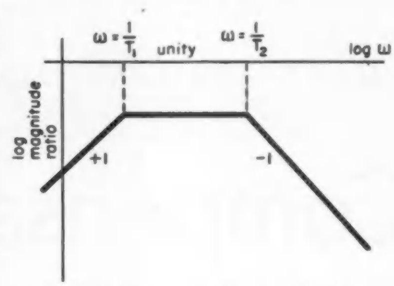
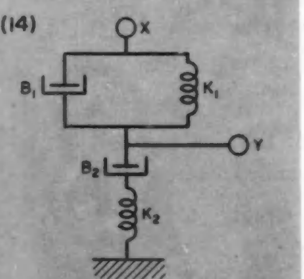
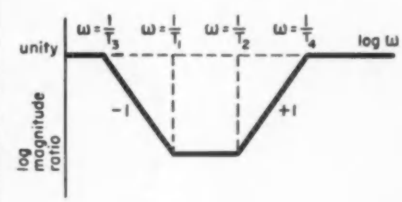
Schematic Diagram	Transfer Function	Log magnitude ratio vs. log frequency
(13) 	approximate $\left\|\frac{Y}{X}\right\| = \frac{T_3 S}{(1+T_1 S)(1+T_2 S)}$ $= \frac{T_3 S}{1+(T_1+T_2)S+T_1 T_2 S^2}$ Exact $\left\|\frac{Y}{X}\right\| = \frac{T_3 S}{1+(T_1+T_2+T_3)S+T_1 T_2 S^2}$ $T_1 \triangleq \frac{1}{K_1 B_1}, \quad T_2 \triangleq \frac{1}{K_2 B_2}$ $T_3 \triangleq \frac{1}{K_2 B_1}$ See note 2	 Where $T_1 > T_2$ break points are as shown If $T_2 > T_1$, reverse labels on break points
(14) 	approximate $\left\|\frac{Y}{X}\right\| = \frac{(1+T_1 S)(1+T_2 S)}{(1+T_3 S)(1+T_4 S)}$ $T_1 \triangleq \frac{1}{B_1 K_1}, \quad T_2 \triangleq \frac{1}{B_2 K_2}$ $T_3 \triangleq \frac{(B_1+B_2)}{B_1 B_2 K_1}, \quad T_4 \triangleq \frac{1}{(R_1+R_2)K_2}$ See note 3	

Note 1: By choice of parameters T_2 can be made larger or smaller than T_1 and thus either a -1 slope or a +1 slope can be synthesized

Note 2: To find the approximate relation B_2 may be considered open or K_1 to be shorted at low frequencies and at high frequencies B_1 to be shorted or K_2 opened

Note 3: The approximation gives

$$\left|\frac{Y}{X}\right| = \frac{\left(1+\frac{S}{K_1 B_1}\right)\left(1+\frac{S}{K_2 B_2}\right)}{1+\left(\frac{1}{K_1 B_1}+\frac{1}{K_1 B_2}+\frac{1}{K_2(B_1+B_2)}\right)S+\frac{S^2}{K_1 B_1 K_2 B_2}}$$

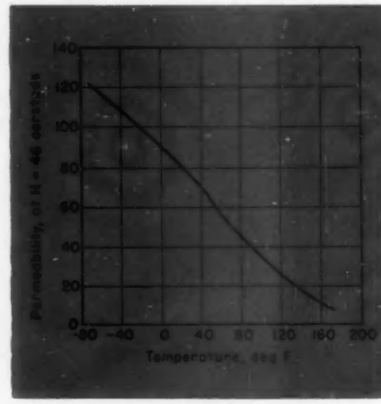
while the exact relation is

$$\left|\frac{Y}{X}\right| = \frac{\left(1+\frac{S}{K_1 B_1}\right)\left(1+\frac{S}{K_2 B_2}\right)}{1+\left(\frac{1}{K_1 B_1}+\frac{1}{K_1 B_2}+\frac{1}{K_1 B_2}\right)S+\frac{S^2}{K_1 B_1 K_2 B_2}}$$

Do You Know Sylphon?

Just after the turn of the nineteenth century, Mr. Weston M. Fulton was the Knoxville, Tenn., weatherman. Not satisfied with the performance of his atmosphere pressure gage, he set out to improve it. The metal bellows that was the fruit of his efforts he named "sylphon."

The word puzzles many people. What is its source? Our staff mythologist assures us that Sylphon was the Norse goddess of the atmosphere.



Variation of permeability of 30 per cent nickel-iron alloy with temperature. FIG. 1

WHAT'S AVAILABLE FOR

Compensating Instruments for Temperature Changes

Once you know how changes in temperature affect instrument accuracy (see CONTROL ENGINEERING, April 1955), the next step is to compensate for these inaccuracies. The table to the right lists the seven more common techniques. The first five of these are covered in this article. Next month's CONTROL ENGINEERING will discuss methods six and seven, and describe specific compensating circuits used in commercially available components.

ROBERT GITLIN, Servomechanisms, Inc.

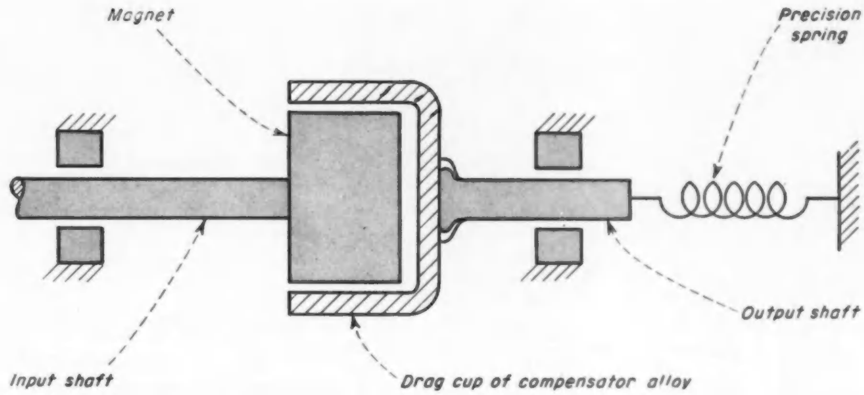
Temperature compensating techniques fall into three general classes: selecting a material unaffected by temperature change, adding elements with properties that vary inversely with those of the element being compensated, and maintaining a constant ambient around the critical element by a control system.

This article discusses materials available for the first two classes.

Magnetic Compensator Alloys

All ferromagnetic materials decrease in permeability as temperature increases. Figure 1 shows the useful portion of this curve for a nickel-iron alloy containing 30 per cent nickel. With a proper selection of field strength, the permeability of certain alloys can be made to decrease almost linearily with an increase in temperature. Thus these alloys can compensate for errors in speedometers, tachometers, watt-hour meters, voltage regulators, and other devices where the calibration depends on the strength of a magnetic field.

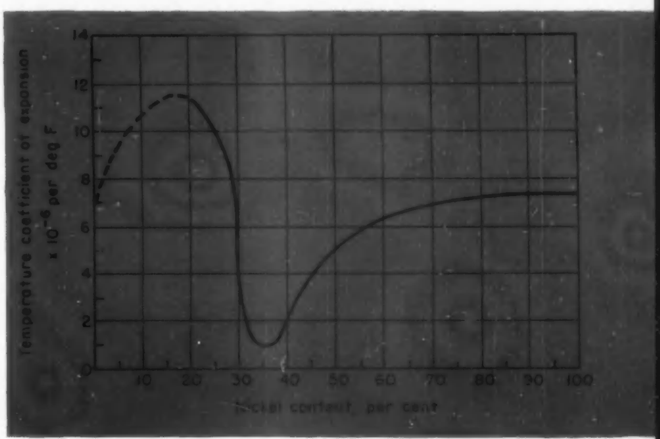
In a noncompensated unit where the flux is supplied by a permanent magnet, the magnet becomes weaker as the temperature increases. To maintain constant flux in the air gap, a compensator alloy shunt can be placed across the poles of the magnet.



Schematic of drag-cup torque tachometer. Output shaft drives a transducer to obtain a useable output signal proportional to angular velocity. FIG. 2

7 BASIC TEMPERATURE COMPENSATION TECHNIQUES USE:

1. *Magnetic compensator metals*
2. *Sensor materials having low thermal coefficients*
3. *Bimetal strips*
4. *Wire with low temperature coefficient of resistance or special temperature properties*
5. *Thermistors (negative-temperature-coefficient resistors)*
6. *Compensator windings in electrical circuits*
7. *Heater and thermostat to keep ambient temperature constant*

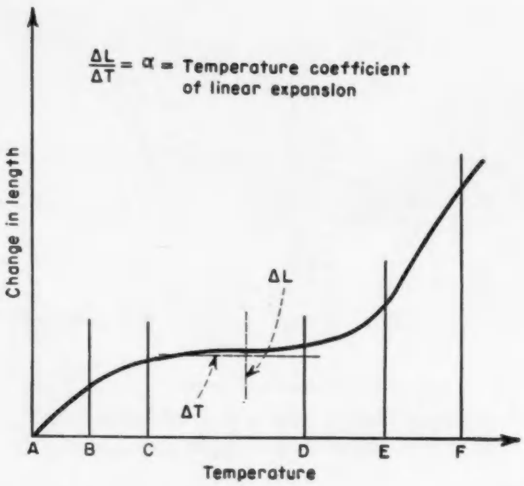


Variation of temperature coefficient of linear thermal expansion with nickel content. FIG. 3

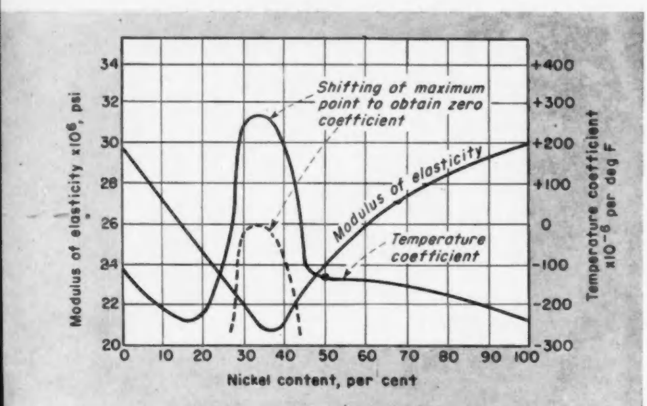
At low temperature the permanent magnet is strong, but the shunt has a high permeability, diverting a portion of the flux from the air gap. As the temperature of the assembly increases the permanent magnet field decreases, but at the same time the permeability of the shunt decreases and less flux is diverted through the shunt. Proper design can make the flux in the air gap increase, decrease, or remain constant over a wide temperature range.

Several types of wrought alloys can be used for magnetic temperature compensation. The most common is a nickel iron with a closely controlled nickel content of about 30 per cent. For a wider temperature range, the nickel content is increased to about 32 per cent, with some loss in the accuracy of compensation. Another is a 70 per cent nickel, 30 per cent copper, precisely proportioned. Cast copper-nickel-iron alloys find similar use. In powdered iron cores, an alloy containing 12.5 per cent molybdenum, 80 per cent nickel, and the balance, iron, is added to the 2 per cent molybdenum, 81 per cent nickel base in the correct proportion to compensate for magnetic temperature effects.

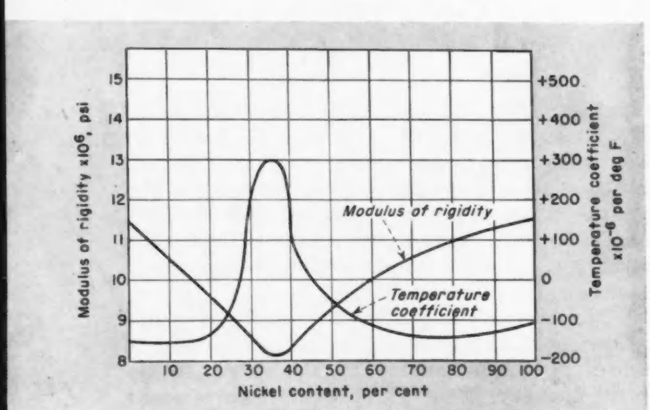
A schematic of a drag-torque tachometer is shown in Figure 2. The rotating input shaft and permanent or dc-excited magnet produce an eddy current torque on the drag cup, causing it to twist a compensated spring. Since the eddy current torque is proportional to the speed of the input shaft, the deflection of the output shaft is a measure of speed. The output



Change in length with temperature of a typical low-expansion iron-nickel alloy (Guillaume). FIG. 4



Variation of modulus of elasticity and temperature coefficient with nickel content in nickel-iron alloys. FIG. 5



Variation of modulus of rigidity and temperature coefficient with nickel content in nickel-iron alloys. FIG. 6.

shaft usually is coupled to a low-torque potentiometer or induction pickup unit.

A change in temperature varies magnet strength and thereby changes instrument calibration. But if the drag cup is made from an appropriate compensator alloy, this temperature error is reduced. One alloy containing 43 per cent nickel, 57 per cent copper or another containing copper and manganese can be used for temperature compensation in this application. Drag cups of temperature compensator alloys are used also with dc tachometers.

Low Thermal Coefficient Alloys

The iron-nickel alloys offer a variety of specialized thermal properties that are useful in compensating for temperature effects. These alloys' characteristics can be controlled by adjusting the nickel content, by adding other metals, or by regulating the conditions of manufacture and treatment. Extensive use has been made of the iron-nickel alloys in applications where dimensional changes must be minimized or where these changes must approximate the dimensional variation of other materials, and in applications where the thermoelastic effects must be controlled, as in instrument and chronometer springs.

Figure 3 shows the coefficient of linear expansion of the iron-nickel alloys at room temperature as a function of nickel content. The composition with the lowest coefficient is in the vicinity of 36 per cent nickel. This alloy maintains such nearly constant dimensions when subjected to ordinary ambient temperature variations that it has received the appropriate name of Invar (invarient or invariable). As the nickel content of the alloys is increased from that of Invar, the expansion coefficient increases continuously, but not uniformly, until it reaches the value corresponding to that of 100 per cent nickel.

When applying these alloys to individual applications, it is important to recognize that their expansivity depends on the temperature range. Thus the values in Figure 3 apply only to room temperatures. The general slope of an expansion-temperature curve of a typical alloy of this group is shown in Figure 4. The interval *CD* corresponds to the range of lowest expansivity and therefore to the most useful temperature range of the alloy. The width and location of the region *CD*, as well as the slope of the curve between these points, will vary with the composition and previous history of the alloy.

Constant Modulus Alloys

Variations in temperature have an unusual effect on the thermal moduli of the iron-nickel alloys. The thermoelastic coefficients of most metals are negative, so that they lose stiffness as the temperature increases. Figures 5 and 6 show that the nickel-iron alloys with nickel contents between 27 and 44 per cent have positive thermoelastic coefficients. Also at the two nickel contents bounding the range of

positive coefficients the coefficient is zero.

These alloys are too sensitive to slight variations in chemical composition to be commercially useful as constant modulus alloys. But by adding other elements it is possible to lower the curve so that the rounded peak is tangent to the zero axis. This, shown by the dotted line in Figure 5, makes the zero coefficient more dependable.

The prototype of these alloys is the well-known Elinvar, which like Invar was the invention of the French physicist C. E. Guillaume. Its name is derived from "invariable elasticity," since its modulus of elasticity is almost independent of temperature over the range from minus 150 to plus 300 deg F. The original Elinvar contained 36 per cent nickel and 12 per cent chromium. But it is now customary to modify the composition through the addition of elements such as tungsten and molybdenum, to obtain or intensify specialized secondary properties.

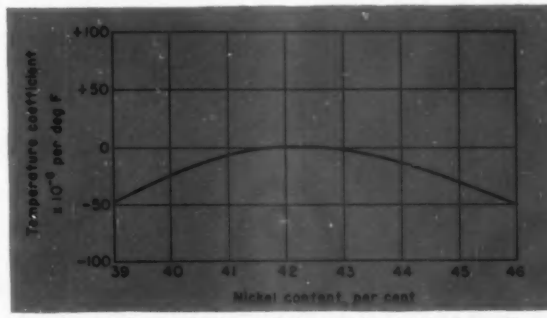
Elinvar has been successfully used for the hair springs of time pieces and other precision instruments. In watches, ordinary steel hair springs have to be compensated for variations in the elasticity of the spring resulting from temperature fluctuations. A brass and steel bimetallic balance wheel is used, cut at two places on the circumference. The substitution of an Elinvar hair spring permits the use of a simpler, one-piece, mono-metallic balance wheel. This construction gives accurate compensation over a wide temperature range, instead of at two definite temperatures.

Constant modulus materials have many other applications, including tuning forks, scale springs, and bourdon tubes. But Elinvar's use has been limited because of its low elastic limit of about 45,000 psi. It can be subjected to only the small deflections that it can support in service. Several means of improving its strength have been tried, including the addition of elements designed to render the alloy susceptible to precipitation hardening.

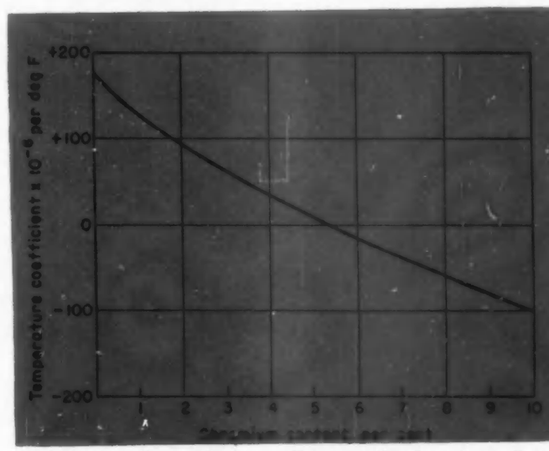
John Chatillon & Son has developed a modified Elinvar type called Iso-Elastic. This contains 36 per cent nickel, 8 per cent or more chromium, and about 4 per cent of other elements including manganese, silicon, molybdenum, copper, and vanadium. After a high degree of cold drawing followed by a moderate heat treatment, it reaches a safe working stress of 60,000 psi in shear and 100,000 psi in tension. Iso-Elastic is suitable for helical springs, spring scales, and other precision measuring elements.

Ni-Span-C is a constant modulus alloy of the Elinvar type manufactured by the H. A. Wilson Co. It contains 42 per cent nickel, 5.5 per cent chromium, and 2.2 percent titanium. Heat treatment will give it a yield strength of about 180,000 psi. An additional advantage is that the thermo-elastic coefficient can be controlled between wide limits by varying the heat treating or aging temperature.

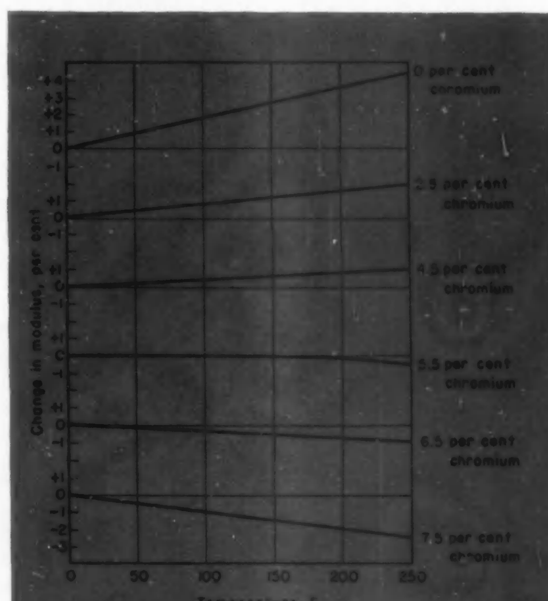
Frequently a small positive or negative value is preferable to a zero coefficient to compensate for



Variation of thermoelastic coefficient with nickel. Base alloy: 5.4 per cent chromium, 2.4 per cent titanium. FIG. 7



Variation of thermoelastic coefficient with chromium. Base alloy: 42 per cent nickel, 2.4 per cent titanium. FIG. 8



Variation of modulus with chromium content. Base alloy contains 42 per cent nickel and 2.4 per cent titanium FIG. 9

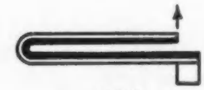
TABLE 1 **PROPERTIES OF TYPICAL BIMETALS**

Bimetal	Temperature range: Useful Deflection, Deg F	Temperature range: Maximum Sensitivity, Deg F	Straight Strips: Flexivity ASTM B106-40 F × 10−4	Straight Strips: K × 10−4	Straight Strips: A	Straight Strips: B × 10+6	Coils: C × 10−2	Coils: X	Coils: Y × 10+4	Modulus of Elasticity lb/in.² × 10+5	Electrical Resistivity in Ohms (square mil-foot) 70°F	(square mil-foot) 300°F	(square mil-foot) 500°F	(circular mil-ft) 70°F	(circular mil-ft) 300°F	(circular mil-ft) 500°F
Standard	−100 to 300	50 to 300	.150	.075	525	70	.095	390	41	175	68	82		87	104	
Highflex	−100 to 700	50 to 300	.138	.069	690	100	.087	510	58	250	375	427		477	544	
Highflex 45	−100 to 700	50 to 300	.150	.075	750	100	.095	555	58	250	372	427		474	544	
Morflex	−100 to 500	50 to 350	.214	.107	815	76	.136	600	44	190	530	623		675	793	
Midflex	−100 to 700	150 to 450	.134	.067	670	100	.085	495	58	250	355	437		452	556	
Midflex 46	−100 to 900	150 to 450	.146	.073	730	100	.092	540	58	250	350	421		446	536	
Highheat	−100 to 1000	300 to 600	.122	.061	610	100	.077	450	58	250	325	396		414	504	
Highheat 47	−100 to 800	300 to 600	.132	.066	660	100	.084	485	58	250	320	400		407	509	
Saflex	+400 to 900	500 to 800	.090	.045	415	92	.057	305	54	230	310	395		395	503	
H.T. Special	−100 to 500	50 to 300	.106	.053	510	96	.067	375	56	240	280	309		357	393	
H.T. Constant	−100 to 700	300 to 600	.096	.048	460	96	.061	340	56	240	260	302		331	385	
Loflex	−100 to 600	50 to 600	.036	.018	180	100	.023	135	58	250	440	492		560	626	
Muflex	−100 to 500	50 to 300	.092	.046	460	100	.058	340	58	250	95	158		121	201	
Ruflex	−100 to 500	50 to 300	.100	.050	500	100	.063	370	58	250	400	439		509	559	
Coflex	−100 to 500	50 to 300	.104	.052	520	100	.066	385	58	250	400	439		509	559	
Cirflex	−100 to 500	50 to 300	.100	.050	520	104	.063	385	61	260	87	135		111	172	
R-24	−100 to 300	50 to 300	.148	.074	520	70	.094	385	41	175	24	31		31	39	
R-39	−100 to 700	50 to 300	.144	.072	720	100	.091	530	58	250	39	43	54	50	55	69
R-56	−100 to 700	50 to 300	.146	.073	730	100	.092	540	58	250	56	76	93	71	97	118
R-70	−100 to 700	50 to 300	.146	.073	730	100	.092	540	58	250	70	93	111	89	118	141
R-97	−100 to 700	50 to 300	.144	.072	720	100	.091	530	58	250	97	123	146	124	157	186
R-118	−100 to 700	50 to 300	.146	.073	730	100	.092	540	58	250	118	181	240	150	230	306
R-157	−100 to 700	50 to 300	.146	.073	730	100	.092	540	58	250	157	225	285	200	286	363
R-203	−100 to 700	50 to 300	.148	.074	740	100	.094	545	58	250	203	273	335	258	348	427
R-245	−100 to 700	50 to 300	.150	.075	750	100	.095	555	58	250	245	316	377	312	402	480
R-310	−100 to 700	50 to 300	.150	.075	750	100	.095	555	58	250	310	361	405	395	460	516
R-372	−100 to 700	50 to 300	.150	.075	750	100	[illegible]	555	58	250	372	427	475	474	544	605
R-440	−100 to 700	50 to 300	.144	.072	690	96	.091	510	56	240	440	488	519	560	621	661
R-530	−100 to 500	50 to 350	.214	.107	815	76	.136	600	44	190	530	623	634	675	793	807

Constants for Formulae in Figure 10

$$d=\frac{KTL^2}{t}$$
$$p=\frac{ATwt^2}{L}$$
$$p=\frac{Bwt^3d}{L^3}$$

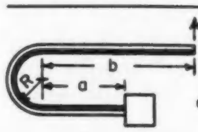
$$d=\frac{KTL^2}{4t}$$
$$p=4A\,\frac{Twt^2}{L}$$
$$p=16B\,\frac{wt^3d}{L^3}$$



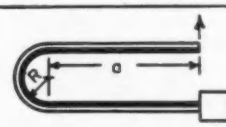
$$d=\frac{KTL^2}{2t}$$
$$p=2A\,\frac{Twt^2}{L}$$
$$p=4B\,\frac{wt^3d}{L^3}$$

Spiral or Helix

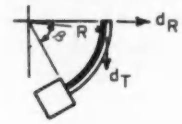
$$\Delta=C\,\frac{TL}{t}$$
$$M=XTwt^2$$
$$M=Y\,\frac{wt^3\Delta}{L}$$



$$d=\frac{KT}{t}\,(b^2-a^2+4R^2+2ab+2\pi Rb)$$

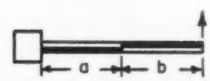


$$d=\frac{2KT}{t}\,(a^2+\pi Ra+2R^2)$$
$$\text{If } R=0,\ d=\frac{2KTa^2}{t}=\frac{KTL^2}{2t}$$

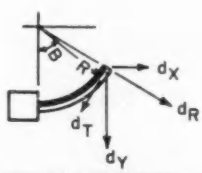


$$d_R=\frac{2KT}{t}R^2\,(1-\cos\beta)$$
$$d_T=\frac{2KT}{t}R^2\,(\beta-\sin\beta)$$

Reverse Welded

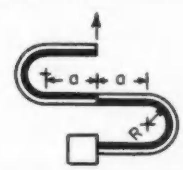


$$d=\frac{KT}{t}\,(b^2-2ab-a^2)$$
$$\text{If } b=2.4a,\ d=0$$

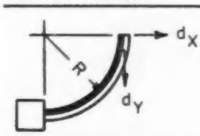


$$d_X=\frac{2KT}{t}R^2\,(\sin\beta-\beta\cos\beta)$$
$$d_Y=\frac{2KT}{t}R^2\,(\beta\sin\beta+\cos\beta-1)$$
$$d_R=\frac{2KT}{t}R^2\,(1-\cos\beta)$$
$$d_T=\frac{2KT}{t}R^2\,(\beta-\sin\beta)$$

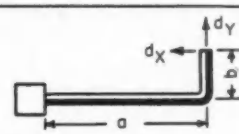
Reverse Welded



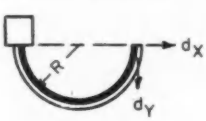
$$d=\frac{4KT}{t}\,(a^2+\pi Ra+2R^2)$$



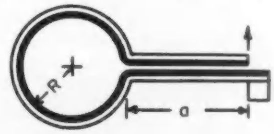
$$d_X=\frac{2KT}{t}R^2$$
$$d_Y=(\pi-2)\,\frac{KT}{t}R^2$$



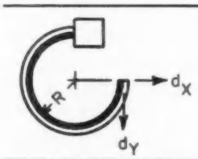
$$d_X=\frac{KT}{t}\,Lb$$
$$d_Y=\frac{KT}{t}\,a^2$$



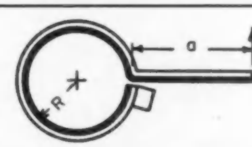
$$d_X=\frac{4KT}{t}R^2$$
$$d_Y=2\pi\,\frac{KT}{t}R^2$$



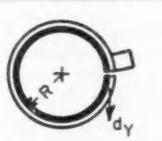
$$d=\frac{2KT}{t}\,(a^2+2\pi Ra+2\pi R^2)$$



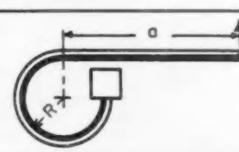
$$d_X=\frac{2KT}{t}R^2$$
$$d_Y=(3\pi+2)\,\frac{KT}{t}R^2$$



$$d=\frac{KT}{t}\,(a^2+4\pi Ra+4\pi R^2)$$

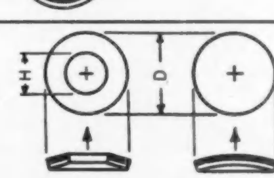


$$d_Y=4\pi\,\frac{KT}{t}R^2$$



$$d=\frac{KT}{t}\,(a^2+3\pi Ra+2R^2)$$

$$d=1.13\,\frac{KTL^2}{t}$$



Washer

$$d=\frac{KT}{4t}\,(D^2-H^2)$$

Disc

$$d=\frac{KT}{4t}\,D^2$$

t = thickness in inches
w = width in inches
L = length inches
d = deflection of free end in inches
p = pull in ounces at free end
M = torque in ounce inches
T = temperature change in F.
Δ = angular rotation in degrees
β = angle in radians
Θ = change in slope in radians

Note: Typical values for constants are given in Table I

Courtesy H. A. Wilson Co.

other temperature effects. A variation of minus 10×10^{-6} to plus 10×10^{-6} per deg F is possible with Ni-Span-C of the above-mentioned composition. The thermal expansion coefficient commonly listed is 4.5×10^{-6} per deg F. Additional changes in the thermoelastic coefficient are obtained by varying the chromium and titanium content of this alloy. Figures 7, 8, and 9 show some of these variations.

Ni-Span-C has been used also for vibrating-reed and similar frequency control devices that depend on magnetic and magnetostrictive properties.

Table II in the April article of this series lists the common spring materials, their chemical composition, modulus and temperature characteristics. These temperature coefficients are accurate averages for the temperature range indicated in the tables. But these average values change somewhat for wider temperature ranges. It is important to use the value of the modulus within the temperature range to which the material will be subjected.

Bimetal Elements

Bimetal elements consist of two metals having different temperature coefficients of expansion, welded together so that they bend when heated. This characteristic has resulted in the application of bimetal elements in many regulatory and control components, especially those associated with the making or breaking of electrical contacts.

Bimetal elements have been used as temperature compensators in on-off devices, such as automobile temperature-compensated cut-off relays, current limiting devices, time delay thermostats, and circuit breakers. They have been used also as temperature compensators in chronometers and instruments.

Basically, bimetal elements provide a zero shift correction as a function of temperature. To correct for scale error with a bimetal element in a proportional-type instrument, it is necessary to change one of the multiplying ratios of the instrument. These elements are available as cantilevers, in U-shape and in spiral or helix coil, as well as for obtaining straight line and zero motion of the end, and other special characteristics.

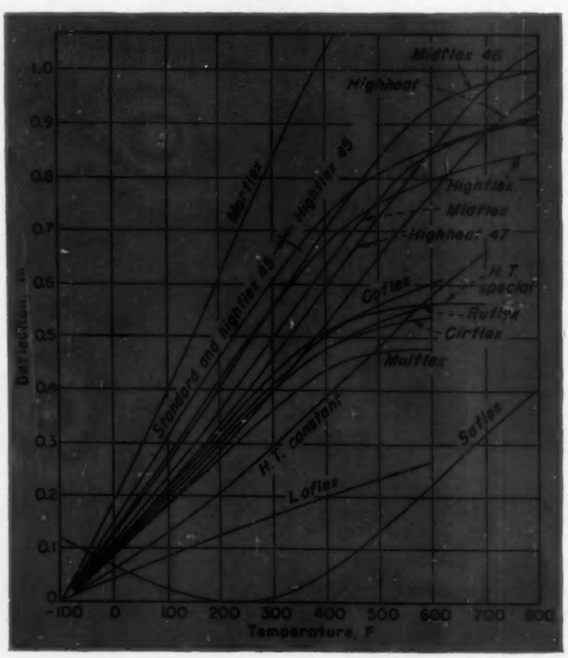
Formulas for the commonly used shapes are shown in Figure 10. Table I lists the properties and constants for the bimetal alloys manufactured by the H. A. Wilson Co. Figure 11 shows their reflections as a function of temperature.

Special Wire

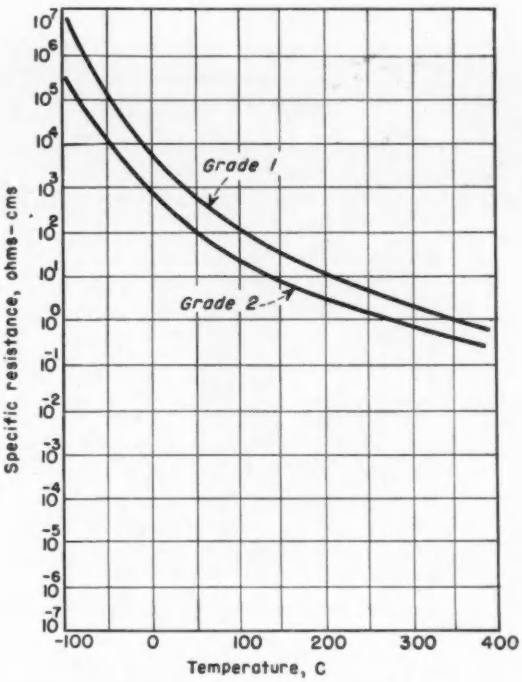
Most electrical elements in instruments contain one or more of the many available wire metal alloys. Special alloys have been developed to meet new requirements, and a designer can choose from many wire types. Wire is available with high or low changes in resistance with temperature, and these can be selected in a manner similar to the selection of low-coefficient spring alloys. These wires can be used also for temperature compensation.

Thermistors as Temperature Compensators

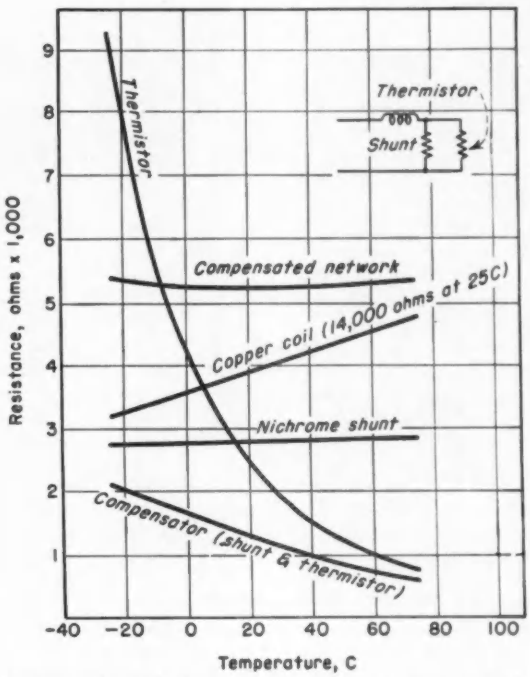
Thermistors are thermally sensitive resistors whose electrical resistance decreases with an increase in



Temperature-deflection curves for various bimetal combinations manufactured by the H. A. Wilson Co. Values given are for 0.050 by 0.25 by 3.16 in. strips. FIG. 11



Specific resistance variations with temperature for two typical thermistor materials. FIG. 12



Compensation technique for wide temperature ranges. Nichrome resistor has slightly positive temperature coefficient. FIG. 13

temperature. The large negative temperature coefficient of thermistors results in unusual nonohmic characteristics suiting them for regulatory functions. Figure 12 shows the variation of resistance with temperature for two grades of themistors over 500 deg C.

To design a circuit using a thermistor for temperature compensation, the thermistor must be exposed to the same temperature as the element being compensated. Also the current through the thermistor must be limited to prevent self-heating of the element.

The following example illustrates the application of a thermistor in a circuit requiring temperature compensation.

PROBLEM: What should be the resistance value and physical size of a thermistor to compensate for the resistance changes of a copper coil having a resistance of 52 ohms at 25 deg C. The current is 0.4 milliamp and the temperature range is 37.8 deg C.

SOLUTION: The positive temperature coefficient of copper is 0.0039 ohms per ohm per deg C. Thus the copper coil will have a resistance of 52.0 minus (52.0 x 0.0039 x 25), or 46.9, ohms at 0 deg. C and a resistance of 52.0 plus (52.0 x 0.0039 x 12.8), or 54.5, ohms at 37.8 deg C. This gives a total resistance change of 54.5 minus 46.9, or 7.6 ohms.

A typical thermistor with a negative resistance change of 7.6 ohms over this temperature range (with maximum average coefficient) has the following resistance values at the specified temperatures.

Temperature, deg C	0	25	37.8
Resistance, ohms	20.7	14.5	13.1

Thus at the various temperatures, the combination of coil and thermistor in series will have resistances as follows:

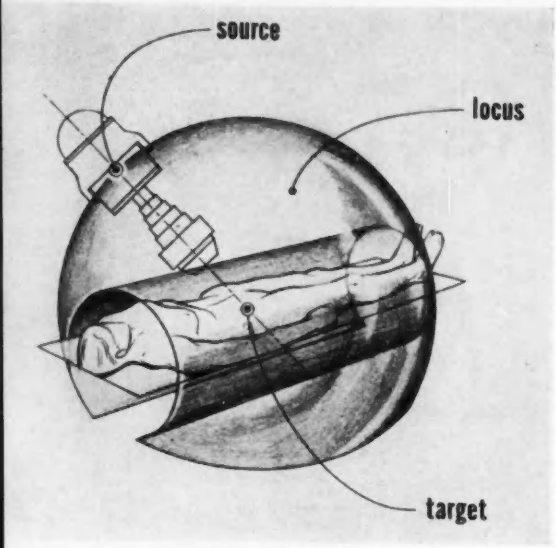
Temperature, deg C	0	25	37.8
Coil resistance, ohms	46.9	52.0	54.5
Thermistor resistance, ohms	20.7	14.5	13.1
Total series resistance, ohms	67.6	66.5	67.6

Therefore the total resistance of the series circuit varies 1.7 per cent over the temperature range, while the coil resistance by itself varies 15 per cent. The maximum wattage to be dissipated by the thermistor occurs at 0 deg C. Since the current carried by the thermistor is 0.0004 amp, this wattage will be

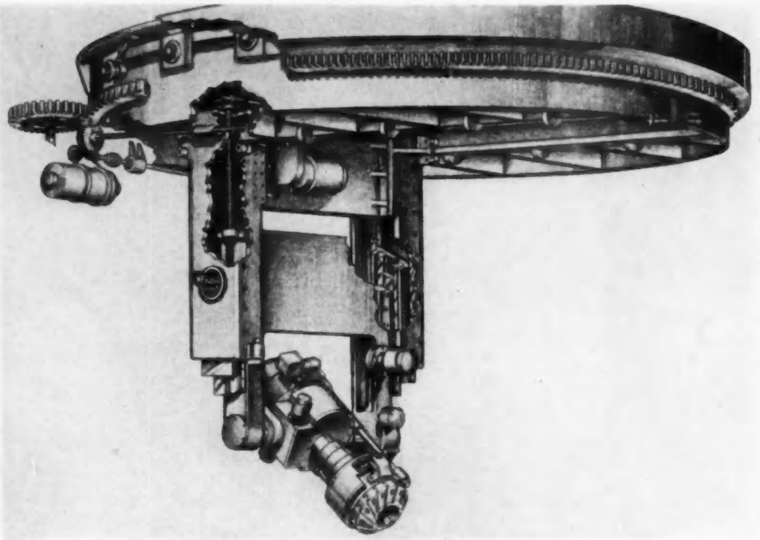
$$W = I^2R = (0.004)^2(20.7) = 0.00000033w$$

This is practically negligible; so a small thermistor can be used.

Temperature compensation over a wide temperature range can usually be accomplished by shunting the thermistor with a material having a slightly positive temperature coefficient of resistance such as nichrome. This method is shown in Figure 13.



Radiation source pinpoints tumor. FIG. 1 . . .



. . . by means of this beam-focusing mechanism. FIG. 2

Moving Source Makes Radiation Therapy Safer

A servo-controlled lead-shielded radiation source follows a computer-generator sphere to concentrate tissue-destroying rays at the tumor.

L. J. BULLIET, W. F. & John Barnes Co.

"Teletherapy" is relatively a new word and does not yet have a clearcut definition. It pertains to the treatment of disease with emanations from radioactive substances. It particularly applies to such treatment when the radioactive material is not embedded in the tissues of the patient's body.

Generally, the rays used for teletherapy are gamma rays from such radioisotopes as cobalt 60 and cesium 137. These rays are similar therapeutically to x-rays from a 1- or 2-million-volt x-ray tube.

X-ray therapists realized early that the benefits of these rays were limited because healthy tissues might be injured by overexposure. It is almost impossible to irradiate a tumor without simultaneously irradiating healthy tissues. Thus the dosage to overlying tissue and tissue beyond the tumor severely limits the amount of treatment possible.

The difficulty has been met partly by a technique called "cross-firing". Here the tumor is given a treatment with the beam passing in one direction through the tumor. The next treatment penetrates the tumor at a different angle. Thus, the tumor gets two treatments but the nearby healthy tissue gets only one. Sometimes it is possible to treat from three or more directions, and for subsequent treatments the different directions are used in rotation.

"Moving beam therapy" is a further refinement. In this technique the angle of the beam changes constantly during treatment, while the tumor remains at the "focal point" or center of motion.

A machine delivered recently to the Medical Division of the Oak Ridge Institute of Nuclear Studies controls movement of a radioactive source of gamma rays over a spherical locus (Figure 1). The rays are directed through a target point fixed in space at the center of curvature of the locus surface—the center, if the locus is a sphere. The radius of the locus is adjustable to permit variation in source-to-target distance.

The cylindrical object suspended between the arms of the fork in Figure 2 is a shielding container for radioactive material. This container or "head" is made of lead clad in steel. A power-driven massive shutter pre-

vents significant passage of gamma rays through the outlet port when no treatment is in progress. The structure provides four basic motions: head tilt, vertical, horizontal across the ceiling ring, and azimuth motion about a vertical axis at the center of the ceiling ring. Any motion desired may be had by coordinating the basic motions. Neglecting the azimuth motion, the remaining three may be coordinated to move the head along a circular arc in a vertical plane.

Specifically, consider the tilt angle with respect to vertical (Figure 1). If this angle alone changes, the beam no longer passes through the target point. If as this angle changes, however, the vertical position of the head changes with the cosine of the angle and the horizontal position with the sine, the source follows the chosen arc of constant radius and the beam stays on target.

The coordinated motions just described sweep the source along a meridian. Rotation of the assembly, in azimuth, about the vertical axis changes the plane of the meridian described. Thus, a combination of motion along the meridian with rotation in azimuth permits the source to be placed at any point on the spherical surface.

The four motions are produced by dc motors position-served to ten-turn potentiometers in the coordinating mechanism, Figure 3. The four potentiometers are labeled "transmitters."

The shaft from the tilt transmitter extends through gearing to a crank arm shown at the right in Figure 3. The crank-pin in this arm engages the slots of two perpendicular Scotch yoke links, which drive the horizontal and vertical transmitters as the sine and cosine of the tilt angles.

Reference back to the description of head motions will show that they provide the coordinating relation between the tilt angle and the horizontal and vertical movements of the radiation head.

Though not shown in the simplified sketch, the distance of the crank-pin from the center of the shaft is adjustable. Thus, the radius of the sphere over which the head passes can be changed to give the source-to-tumor distance needed for treatment.

The tilt transmitter shaft can be driven by the "tilt motor" or by the "tilt cam." A magnetic clutch, between the tilt motor and the gear that meshes with the tilt-cam follower rack, connects either the motor or the cam, but not both, to the tilt transmitter.

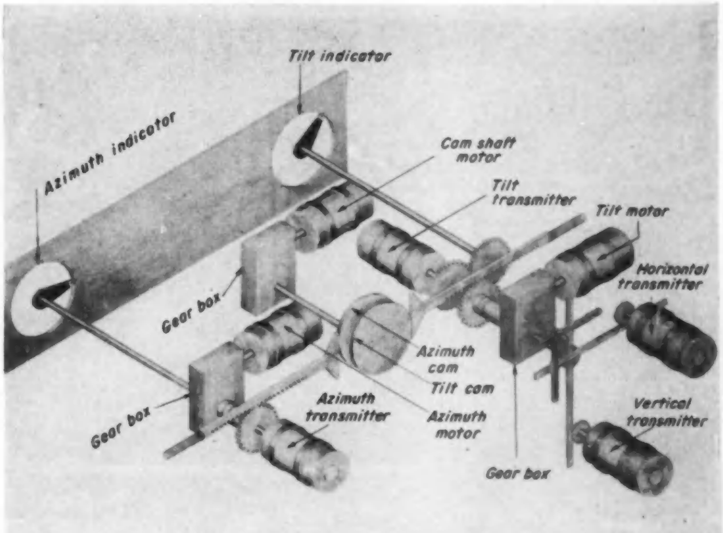
The azimuth transmitter also may be driven from the "azimuth motor" or in response to the "azimuth cam" which is mounted on the same shaft as the tilt cam. The cam shaft which carries both the tilt cam and the azimuth cam is driven by another variable-speed motor designated as the "cam-shaft motor."

There are pushbutton controls for each of the three drive motors. These motors may be started, stopped, and reversed, and their speeds are variable independently.

Conical or other specialized motion can be generated by specially prepared cams, driven at the proper speed by the cam-shaft motor. These special cams are made by manually maneuvering a desk-sized model of the machine and plotting the readings of indicators on the model. A near-infinite variety of travel paths can be duplicated accurately by properly shaped cams.

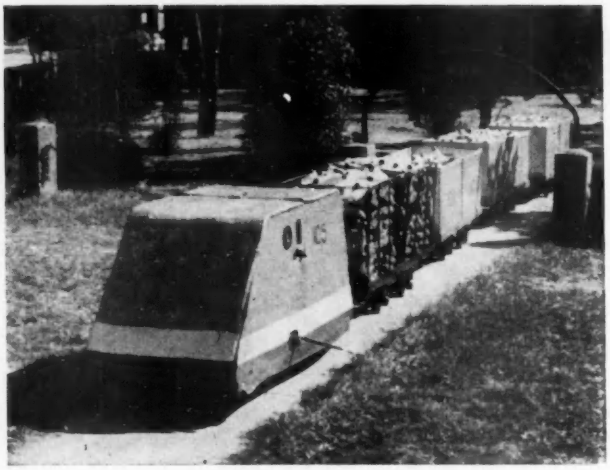
The very sensitive servo amplifier has two stages of magnetic amplification followed by a pair of thyratron tubes, which supply current to the motor. The thyratrons are connected "back-to-back" in a half-wave, controlled rectifier circuit. When the unbalance voltage is of one polarity, the magnetic amplifier causes one thyratron to conduct and drive the motor to reduce the unbalance. An unbalance of the opposite polarity causes conduction of the other thyratron and the motor runs in the reverse direction.

The operator of this machine stays in a room adjacent to the treatment room while a treatment is in progress. A massive concrete wall between the operator and the machine protects him from the gamma rays. He may view the patient through a window which is transparent to light but relatively opaque to gamma rays.



Electromechanical analog computer derives orthogonal components of tilt and for vertical and horizontal positioning of head. FIG. 3

Robot Train Follows Unseen Rail from Plant to Plant



K. ASAI and Y. HABU, Kanegafuchi Spinning Co., Ltd.

Savings in operators' salaries paid off the cost of these unmanned trains in less than two months.

The Sumoto Mill of Kanegafuchi Spinning Co., Ltd. is one of Japan's biggest, producing 8,800,000 lb of cotton yarn and 31,500,000 yards of cotton piece goods each year. 14,600 lb of yarn must be carried each day over the ½ mile route from the spinning plant to the weaving plant, and until recently this job required human workers.

Because the route is outdoors and not straight, a conveyor system would be quite expensive. A very simple battery-powered electric train (see cut) has proved an excellent answer to the problem.

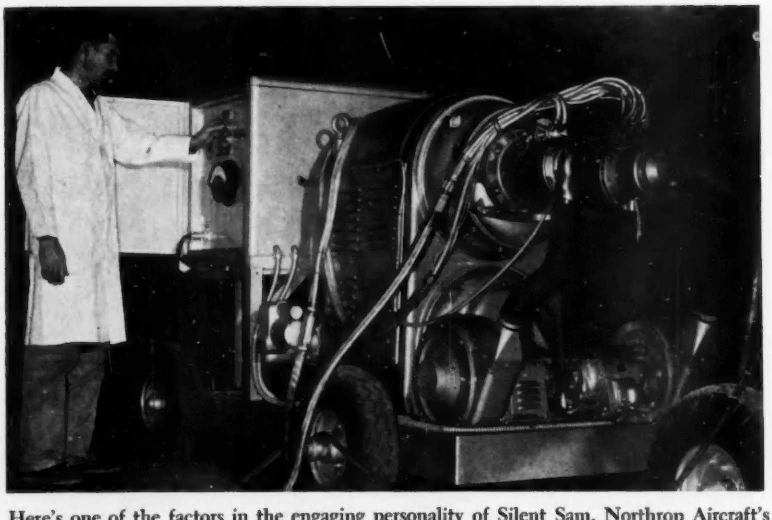
The locomotive is three-wheeled, the single front wheel being pivoted for steering. An electromagnet attracted to an iron strip laid under the paved road is linked to the steering wheel and acts as pilot. The iron strip is an unseen rail, which the train follows from the spinning plant to the weaving plant.

The train is not dangerous to pedestrians because it is so small, about 22 in. high, and moves so slowly, about 2 mph. And an emergency stop switch is built in the front bumper.

In normal operation the train is stopped at the end of its run by a bar that trips the lever that can be seen extended from low on the side of the locomotive. To make the operation completely automatic, the doors of the plant buildings are relay-operated to open and close as the train approaches or leaves.

The entire cost of the development and installation was payed off in less than two months.

Jet Engine Gets Silent Treatment at Northrop



Here's one of the factors in the engaging personality of Silent Sam, Northrop Aircraft's electro-mechanical engine circuit inspector. It's one of two 50-hp variable drives that simulate the engine being tested. In the picture it's at work on a Scorpion F-89D.

There's a hush around Northrop Aircraft's assembly line these days. It's due to good breeding—and design—of Silent Sam, the stoical electro-mechanical engine circuit inspector.

Silent Sam was pieced together from some vari-drives, a load simulator, control boxes, and some octopus-like connecting cables. As a unit he is capable of neatly checking out a Scorpion F-89D's engine circuitry—and before the power plant gets into the airframe. Sam's quiet efficiency has cut down engine runup time from eight to two hours—and has slashed the thunderous test decibels by a proportionate factor.

While it takes 40 minutes for Northrop test engineers to hook up the silent simulator, it requires only five minutes for the actual survey of all circuits which lead to and from the turbojet engine. Two 50-horsepower drives right on Sam's roller platform simulate the engine.

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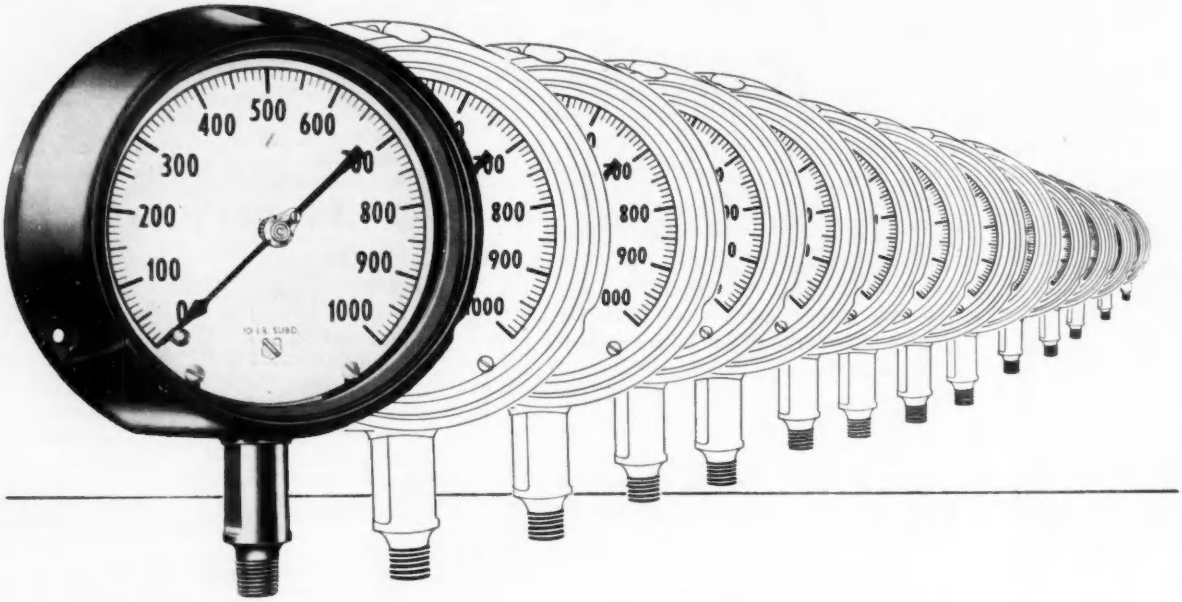

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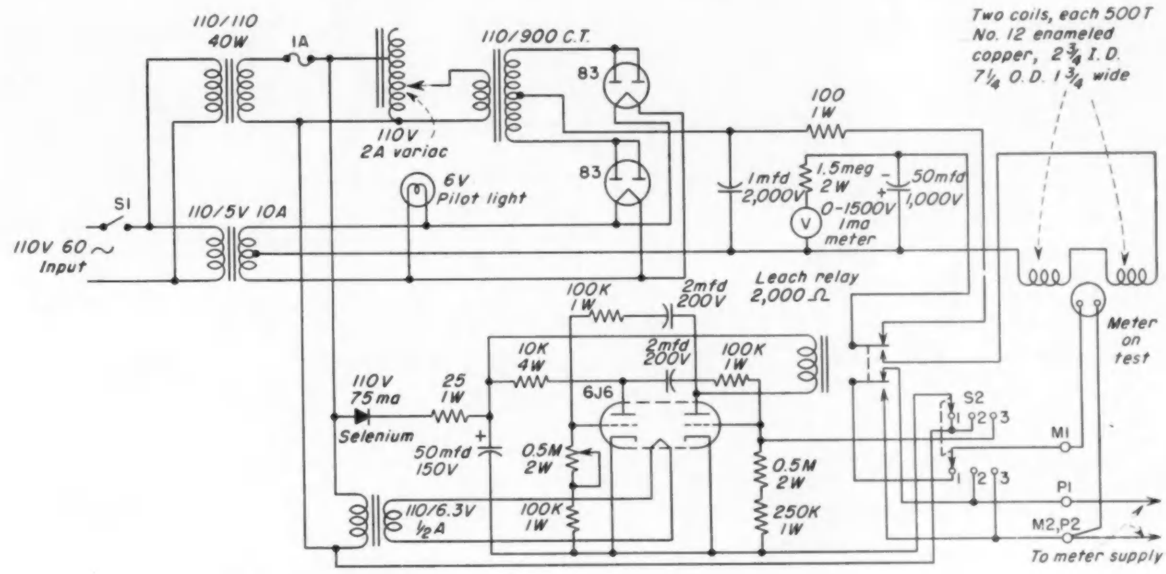

This demagnetizer doesn't need a high-power source, can't get off resonance, has inexpensive control elements, and gives reproducible results—to cite a few of its advantages.

Calibrate Instruments with a Self-Resonant Demagnetizer

F. J. LINGEL and V. T. BURKETT
General Electric Co., Syracuse, N. Y.

The magnet of an electric indicating instrument generally is charged to saturation during manufacture. The instrument's control springs then are cut to give a somewhat high indication for full-scale current. Final instrument calibration is made by "pulling down" the magnet until the instrument indicates precisely full scale on an accurate calibration current.

Pull down means reducing magnet air-gap flux and is done by applying to the magnet an alternating flux that decreases with time. A very large number of ampere-turns is needed. Most demagnetizers for this purpose use the 60-cps line directly and force a large current through the pull-down coils by some method such as:

▶ Stepping up the line voltage from 110 to 440
▶ Tuning out the demagnetizing coil inductance with several microfarads of capacitance.
▶ Using large-wire low-resistance demagnetizing coils and momentarily overloading them
▶ Applying fractions of a cycle to the coil through a thyratron switching circuit

SELF-RESONANT DEMAGNETIZER

The demagnetizer of Figure 1 produces a self-resonant ac pulse of gradually decreasing amplitude by simply discharging a condenser through the demagnetizing coils. The condenser is alternately charged and discharged through a multivibrator-timed relay. The charge is slow, from a low-power dc supply with a small Variac control. The discharge is fast, having a peak current of 40 amp that decays to zero in ⅛ sec with the waveform of Figure 2.

Some other facts about the circuit shown: maximum charging voltage, 1,200 vdc; 1,000-turn coil gives 40,000-ampere-turn demagnetizing force; self-resonant frequency, 122 cps. These factors are obviously variable.

In Figure 1, switch 2 shorts the meter terminals for zero check during the demagnetizing pulse when in position 1. In position 2 the meter is connected all the time, even during the ac pulses. Position 3 turns off the demagnetizer (multivibrator grid shorted) and shorts the meter for zero check.

MANY, MANY ADVANTAGES

This demagnetizer system has many advantages over usual methods. For example, it:

▶ Eliminates possible damage to instrument pivots, jewels and springs by using higher ac flux frequency. The usual 60 cps line frequency can cause considerable vibration of the moving element resulting in damage to pivots and jewels and distortion of the control springs.
▶ Removes demagnetizing flux peri-


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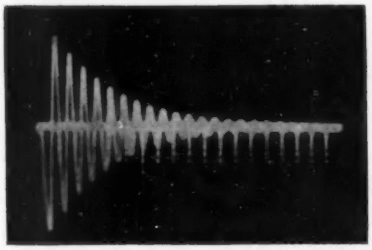


Output of the demagnetizer is a highly damped oscillation. Peak current is 40 amperes; markers are 5 millisec. apart. FIG. 2

Demagnetizer in a typical calibration setup. FIG. 3

odically by applying ac in shaped pulses. This helps establish a steady meter reading and permits more accurate setting of the demagnetizing coil current for proper adjustment. With present methods pointer vibration often results in demagnetizing too far.

► Eliminates heavy power line surges which can disturb calibrating equipment connected to the same ac lines. This is done by taking the demagnetizing energy from the condenser in a large pulse for a short time and charging the condenser at relatively low current for a longer time.

► Eliminates need for running special high current ac line for the same reason.

► Reduces size, weight, and cost to approximately one-third that of demagnetizers of the usual design, which need also special transformers, control Variacs, condensers, and connectors.

► Permits smooth fingertip control on a small Variac. This means more accurate setting of the current in the demagnetizing coils.

► Causes less zero shift and scale distortion of the instrument being calibrated because of high flux density, higher frequency, and smoothly decaying pulses. All the factors that influence the final magnetic field are uniform from one instrument to the next, promoting uniformity of calibration. These factors are demagnetizing flux peak magnitude, pulse decay rate, time between pulses, frequency, and build-up time of pulse.

► Gives higher demagnetizing force and thus permits setting the coils for more nearly parallel flux lines. This also helps toward less zero shift and scale distortion.

► Gives full demagnetizing action, practically independent of the size of the device being demagnetized. The coil and condenser are always self-resonant (although the frequency varies) regardless of the amount of iron in the coil. In the 60-cps condenser-tuned systems the resonant point depends on the iron in the demagnetizing coil and with large instruments or steel panels these combinations are often off resonance and full flux cannot be reached.

► Uses a small inexpensive relay with relatively light contacts to establish the pull-down pulses, because on both contact breaks zero current is flowing in the contacts. That is, on the charge cycle, the contact breaks only after the condenser is fully charged and contact current is zero. On the discharge cycle the contact breaks after the condenser is fully discharged and the contact current is again zero.

► Allows ready adjustment of the demagnetizer frequency by changing the values of the charging capacitor and the demagnetizer coil. This permits optimum demagnetization of different magnetic materials with various thicknesses and shapes.

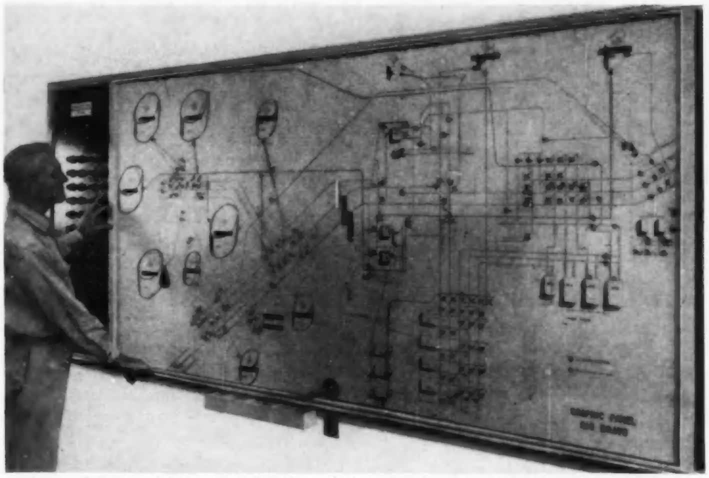
► Permits shaping the demagnetizing pulse by several means to permit the proper degree and kind of demagnetization. One example is the pulse shape that may be needed on special sensitive indicating instruments, where a gradual pulse build-up from zero to maximum, would still further reduce the shock on the moving element. This can be done by adding a coupling transformer between the charging condenser and the demagnetizing coil. The pulse in the secondary would then start from zero, gradually build up to a maximum, and decrease again to zero.

► Makes possible different pulse lengths. For example, resistance in series with the coil lengthens the pulse, and using pie coils or bank windings in the inductance increases the Q of the system and shortens the pulse.

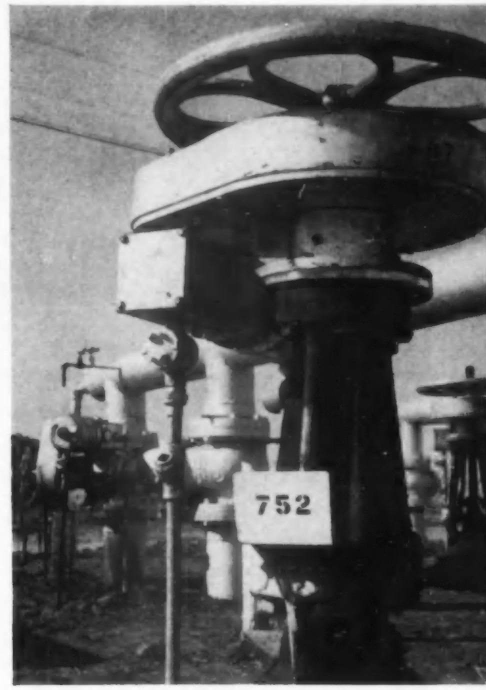
Two of these self-resonant demagnetizers have been in use by General Electric for almost two years. Both units have given very satisfactory service and have definitely contributed to faster and more accurate instrument calibration.

RELATED READING

1. *MAGNETIC AND ELECTRICAL METHODS OF NON-DESTRUCTIVE TESTING,* D. M., Lewis, George Allen and Union Ltd. London, 1951, pages 78-91.
2. *INTRODUCTION TO ELECTRICAL ENGINEERING,* G. V. Mueller, McGraw-Hill Book Company, Inc., New York, 1948—2nd Ed., pages 285-286.
3. *RESONANT AND TRANSIENT THEORY APPLIED TO CONTROL POWER IN DEMAGNETIZING,* General Motors Engineering Journal, Vol. 8, Sept. 1954, pages 34-37.



A graphic panel in a central office of the Rio Bravo station completely controls the pumping of 80,000 barrels per day of crude oil and the storing up to 880,000 barrels. Measurements of tank gage and tank average-temperature are brought to other panels in the same office. FIG. 1



The electric-motor-driven valve operator adapts to the valve stem. On rising stem valves (shown), it operates the yoke nut which is ordinarily driven by the hand wheel. On non-rising stem valves, it attaches directly to the stem in place of the hand wheel. FIG. 2

Rio Bravo Pump Station Goes Automatic

J. S. PATTERSON and W. B. KNUPP*

From the oilfields in the southern end of California's San Joaquin Valley, the Rio Bravo gathering and pumping station accumulates various types of crude and pumps them to the refineries. Its equipment—including an aggregate storage of 880,000 barrels, seven steam-driven main line pumps and oil heaters, ten boilers, 215 valves with an average size of 8-to-10 in., and two Zeolite water-treating plants—sprawls over 80 acres.

In a plant of this nature the control engineer aims to bring all instruments and control adjustments to one point so that the operator may control the plant from one central "driver's seat." Without centralized control, the operator is out of touch with most of the 80-acre plant. A graphic panel mounted on one wall of the station office centralizes the operation. The panel, Figure 1, shows lines, tanks, valves, and other oil-handling facilities. Valve-indicator lights are installed in the location of the valve with which they are associated. Pushbuttons at either side of the panel control the remote valve motors.

* Authors are pipe line engineer and chief engineer, respectively, Pipe Line Department, Standard Oil Co. of California, Western Operating Division.

VALVE OPERATION

A careful analysis determined frequent and infrequent operations. Controls for the frequent operations were brought into the central control room, whereas the infrequent ones were left on manual, local control. Because only 32 of the many oil valves in the yard required frequent operation, the remotely controlled electric motor operators shown in Figure 2 were installed on them only. A "hammer blow" device starts the valve. Motion-limit switches stop the valve at its fully-opened and fully-closed positions. A torque-limiting switch prevents overstressing the valve or operator parts during the closing cycle when there is an obstruction in the valve and assures solid valve seating.

TANK GAGING

The operator must be able to determine accurately oil height in the tanks. A gaging error of only 1/8 in. in one of the large tanks means a volumetric error of about 30 bbl. The remote-reading Selsyn tank-gaging system shown schematically in Figure 3 is installed. It has proved accurate to within 1/16 in. The Selsyn receivers connect through field relays to each Selsyn transmitter. When the operator positions the selector switch for a particular tank and pushes a reset button, the field relay at that tank is energized, the two pairs of Selsyns synchronize, and the receiver dials indicate the level of oil in the tank.

TANK TEMPERATURES READ REMOTELY

Because petroleum expands and contracts considerably with temperature changes, volumetric calculations must be temperature-corrected. The averaging resistance temperature instruments, installed as shown in Figure 4, read remotely to within 1/2 deg F error.

The resistance elements, a stepping switch at each tank, and a tank-selector switch at the indicating potentiometer in the station office, are the

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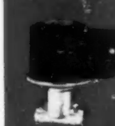
More and more designers find one simple rule short-cuts their control problems with a quick solution: "Check General Controls first!" For the chances are the complete GC line has the perfect answer to your problems whether it's a time switch or thermostat, a midget solenoid or mighty hydramotor. Get acquainted with the branch office (one of 38) nearest you . . . one source—one responsibility—near at hand—at your service.

K-21 MAGNETIC STOP VALVE

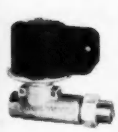


Packless—2 way—normally closed. For air, gas, steam, water, oil, corrosive fluids. Pressures to 300 psi. Forged brass body. Stainless steel or soft seat.

K-27 MAGNETIC VALVE

Stainless steel for high sulphur fuels, syrups, juices, acids, alkalis, etc. Pressures to 300 psi. Midget size. Multi poised—operates in any position.

K-10 MAGNETIC VALVE



Lever action for higher seating pressure. Excellent general purpose valve for primary fuel, feed water, steam, air. (300 psi max. operating pressure differential.)

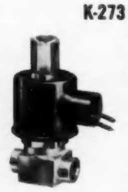
K-15 MAGNETIC VALVE

Piloted piston design. Large flow capacity with low pressure drop. For air, gas, steam, oil derivatives. Versatile—with 3 coil classes, 5 seat variations.

K-123 MAGNETIC VALVE

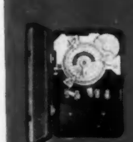
3 way—for normally open or normally closed directional control and mixer applications—on pneumatic or hydraulic operated devices, machine tools, etc.

K-273 MAGNETIC VALVE



3 way flow or mixer type. Compact, multi poised. For air, water, hydraulic fluids—charging or emptying systems. Normally open or closed. Choice of flow patterns.

TIME SWITCHES



Wide selection for domestic and commercial use—spring wound or motor driven, normally open or closed. For ventilating, lighting, refrigeration, etc.

HYDRAMOTORS

Wide range of types in complete range of pipe sizes and body styles to provide safe, dependable, durable answer to all liquid transfer problems.

AIR MOTOR VALVES

Air-operated diaphragm valve for modulating control. Normally open or closed, 3 way, or slide gates. Selection of various inner valves, body sizes and connections.

General Controls *Automatic* Control Line

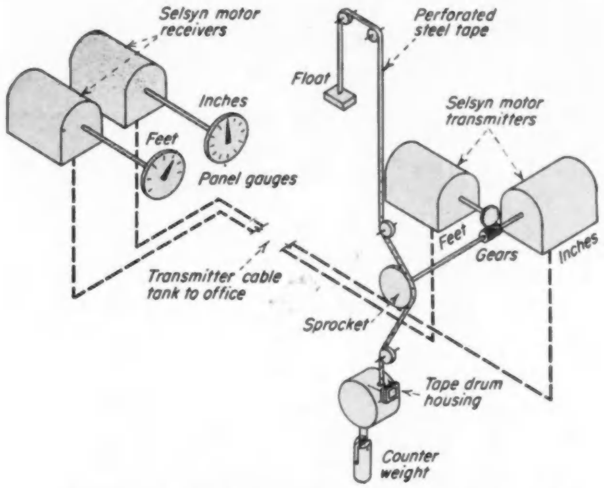
1930 25 YEARS 1955

1955 SILVER JUBILEE YEAR

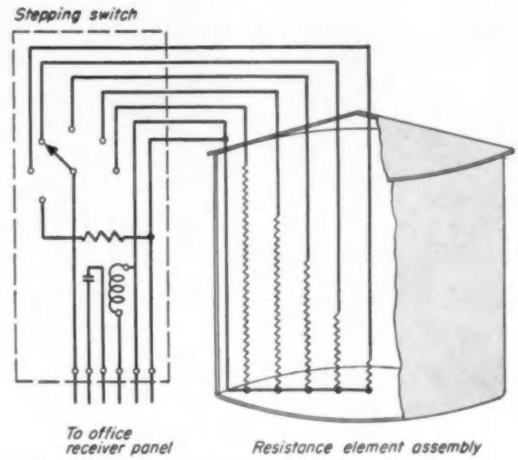
GENERAL CONTROLS

PLANTS: GLENDALE, CAL. • BURBANK, CAL. • SKOKIE, ILL. • 38 BRANCH OFFICES SERVING THE NATION

MANUFACTURERS OF AUTOMATIC CONTROLS FOR THE HOME, INDUSTRY AND THE MILITARY



Arrangement of primary components of automatic tank gage systems using Selsyns for remote transmitting and receiving of readings. The several transmitter pairs share a single pair of receivers through selective switching. FIG. 3



Resistance temperature elements connect to stepping switches controlled from the indicator in the station office. Each element reads average temperature over a range of liquid level: 3 ft to 5 ft, 5 ft to 7 ft, etc. FIG. 4.

components of the system. To read average liquid temperature in a particular tank, the operator positions the tank-selector switch. Then he depresses the liquid-level switch that corresponds to the level in the tank. This supplies a pulsing voltage through an interrupter relay until the stepping switch reaches the proper position. After the temperature has been taken, the stepping switches return automatically to reference position.

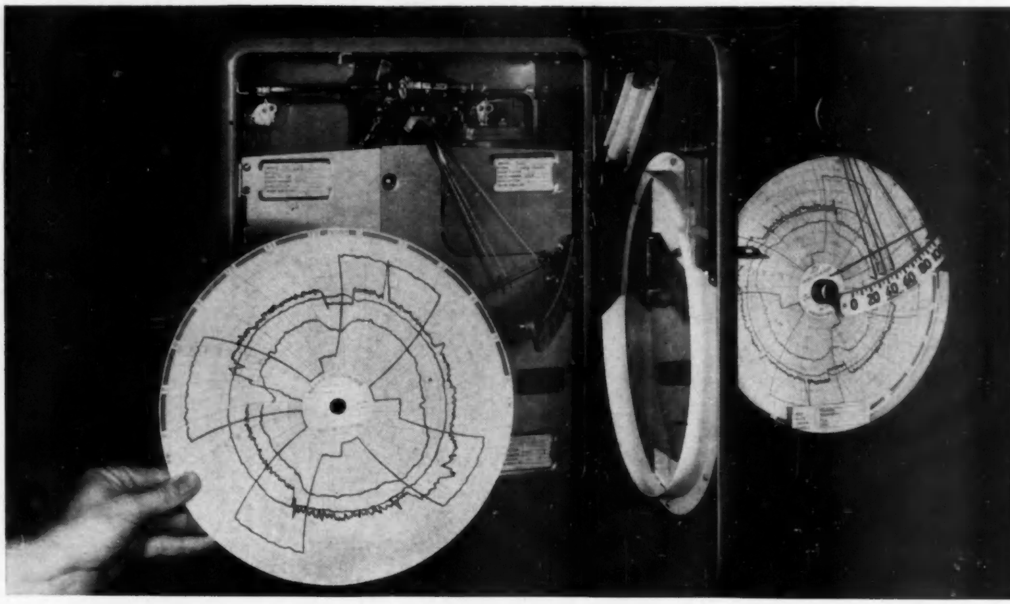
In several tanks, considerable water settles out of the oil and accumulates in the bottom. This water must be bled off more or less continuously so that it will not be delivered out of the station with the crude oil. An electronic capacitance instrument, with plates at the desired elevation of the oil-water interface, operates a relay at a set capacitance. The relay opens a water bleed valve until the interface returns to within the dead-band.

The station features many more instrumentation and control devices. Most of this equipment, plus that used in the boiler plant, is pneumatic:

- ▶ Recording gravitometer which weighs a fixed volume of oil
- ▶ Oil temperature control
- ▶ Main line pump control: Manipulation of supply steam valve controls pump discharge unless suction drops too low or pump rotates too fast, when overriding controls take over.

AN ELEPHANT IN THE BOOTH . . . . . . AND EQUIPMENT IN ROOM 984

Benson-Lehner solved its space problem at the recent Western Computer Conference in Los Angeles by setting up a working display upstairs.



Faithfully yours -

Clear, Continuous Records without Poisoning . . . on the New Bailey Recorder

★ Faithful chart records of measured variables are the key to a meaningful, dependable analysis of operating trends and conditions. Money spent for more accurate metering, for faster response, is money down the drain—*unless* it's matched with chart records that are equally accurate

That's why these features of the new Bailey Recorder are important to you:

1. Bailey's exclusive sealed capillary-action inking system maintains continuous flow to the pen tip, and traces sharp, opaque, quick-drying records. "Poisoning" of intersecting records is practically eliminated; no blots or smears during operation or chart changing.

2. Pens are mounted on concentric centers, trace on parallel time arcs only 42/1000" apart. This simplifies analysis of two or more records.

3. Interchangeable plug-in receiver units permit practically limitless record-grouping combinations.

Write for Product Specification E12-5 and actual chart sample.

P32-11

ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER

- Pre-calibrated plug-in receiver units
- Up to four pneumatic or electronic receivers —or two receivers and two integrators
- Any four variables on one chart—easily read and interpreted
- A full year's ink supply at one loading
- Faster shipment—from stock
- Minimum inventory of parts
- Minimum instrument investment for process cycle expansion or alteration

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METER COMPANY
1079 IVANHOE ROAD
CLEVELAND 10, OHIO
Controls for Power and Process

Controls for
TEMPERATURE
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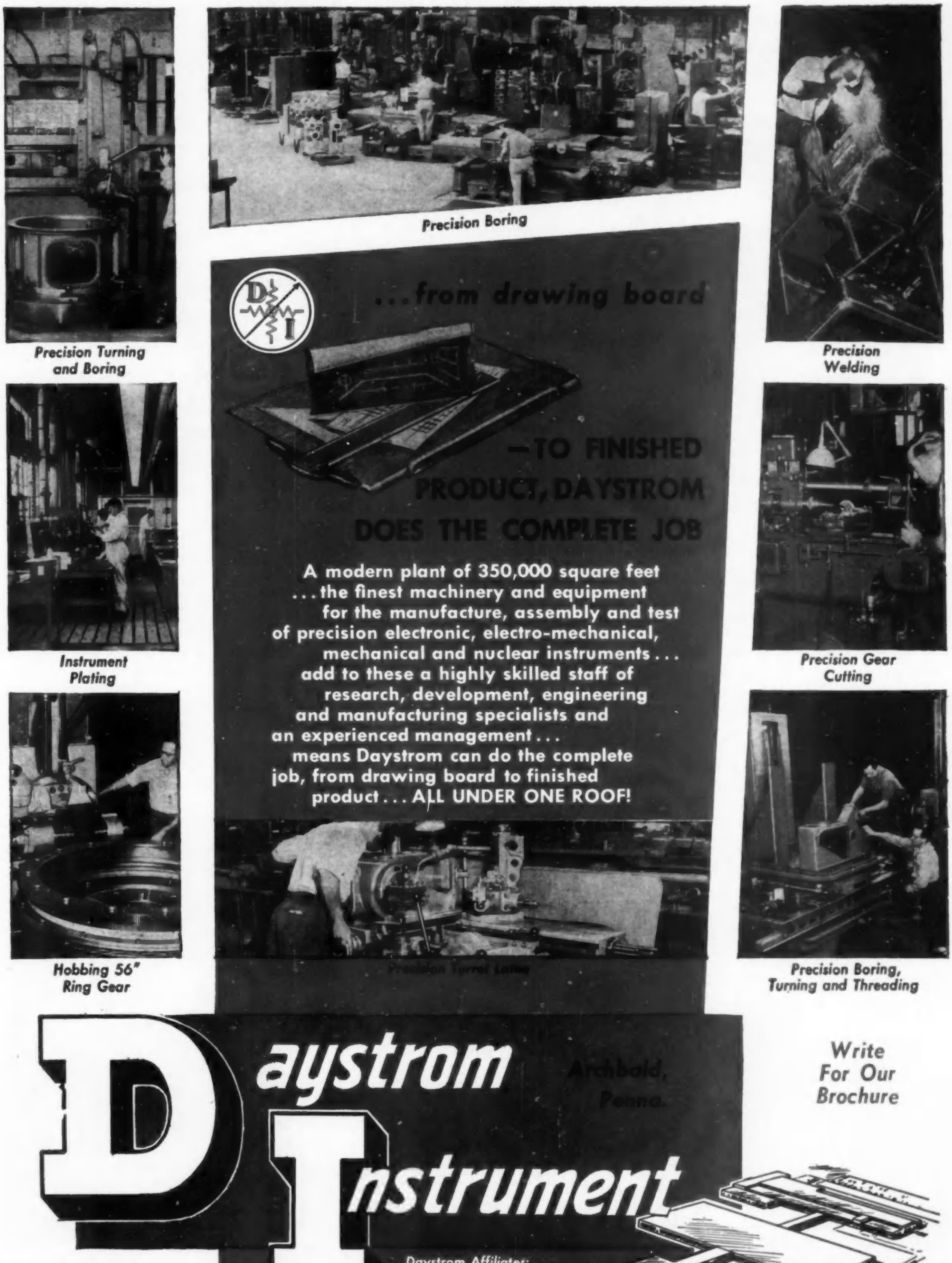
FLOW · LEVEL
RATIO · DENSITY


Precision Turning and Boring
Precision Boring
Precision Welding
...from drawing board
—TO FINISHED PRODUCT, DAYSTROM DOES THE COMPLETE JOB
A modern plant of 350,000 square feet ... the finest machinery and equipment for the manufacture, assembly and test of precision electronic, electro-mechanical, mechanical and nuclear instruments ... add to these a highly skilled staff of research, development, engineering and manufacturing specialists and an experienced management ... means Daystrom can do the complete job, from drawing board to finished product ... ALL UNDER ONE ROOF!
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Precision Gear Cutting
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Write For Our Brochure
Division of Daystrom, Inc.
Daystrom Affiliates:
American Gyro; Heath Company;
Daystrom Electric Corp.;
American Type Founders, Inc.;
Daystrom Furniture Div.

NEW PRODUCTS

LISTING IN GROUPS

PRESET COUNTER with electronic and electromechanical components controls and indicates machine motion.

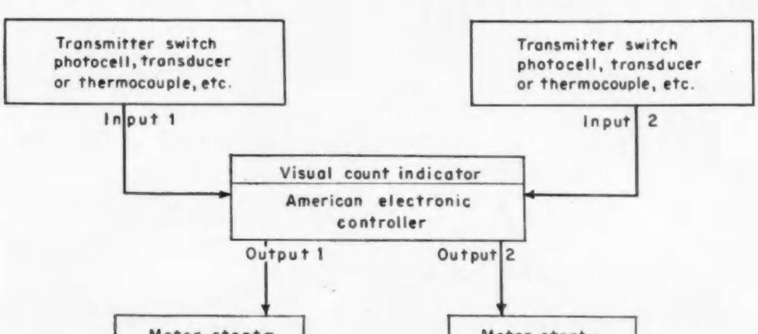
Machine control through pulse count is the function of this product. Simple, rugged, and using economical electro-mechanical parts, it alternately counts two series of pulses for proportional or motion control. Counting at rates up to 20 cps through two 50 position stepping switches, it records a maximum of 2500 counts on each of its two counting sections. Count is indicated by Inditron counter tubes.

Shown above is its application with a Sheridan-Gray 40-ton stretch-wrap forming machine. The controller's function here is the limit and indication of the forward-backward motion of an hydraulically-operated die used for forming aircraft door-frames. The transmitter in this case is a 16 pole commutator which triggers the grid of a thyratron in the receiver by charging and discharging a capacitor connected across the commutator bars. The transmitter is driven by a chain drive. Photocells could be the pick-up used. Set-up time is saved because on a re-run the known numbers can be quickly programmed simply by setting the count switches.

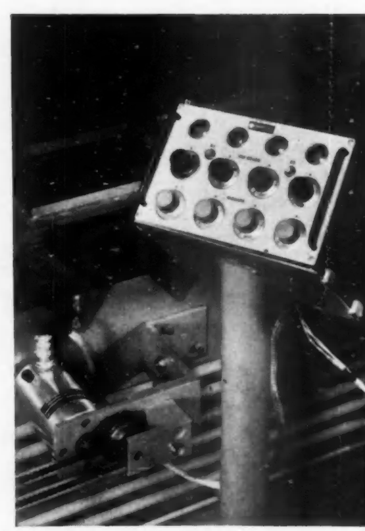
When the count of the stepping switches reaches one of the two four-digit preset numbers on the instrument's face, a driver tube operates a relay and provides an output control signal. A separate counting circuit operates similarly, as shown in the block diagram, providing the controller with two inputs and two outputs. Uses in batch mixing operations, conveyor systems, and similar, are also envisioned. American Electronic Mfg., Inc. *Instrument Div. of American Electronics, Inc., 9503 W. Jefferson Blvd., Culver City, Calif.*

Circle No. 1 on reply card

The block diagram ↓



Closeup of Control Station →

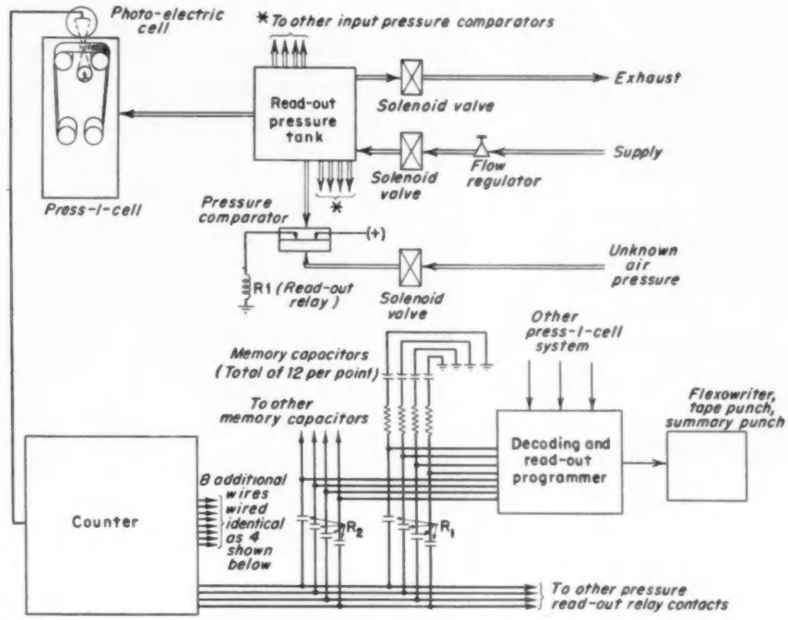


OTHER UNUSUAL SYSTEMS →

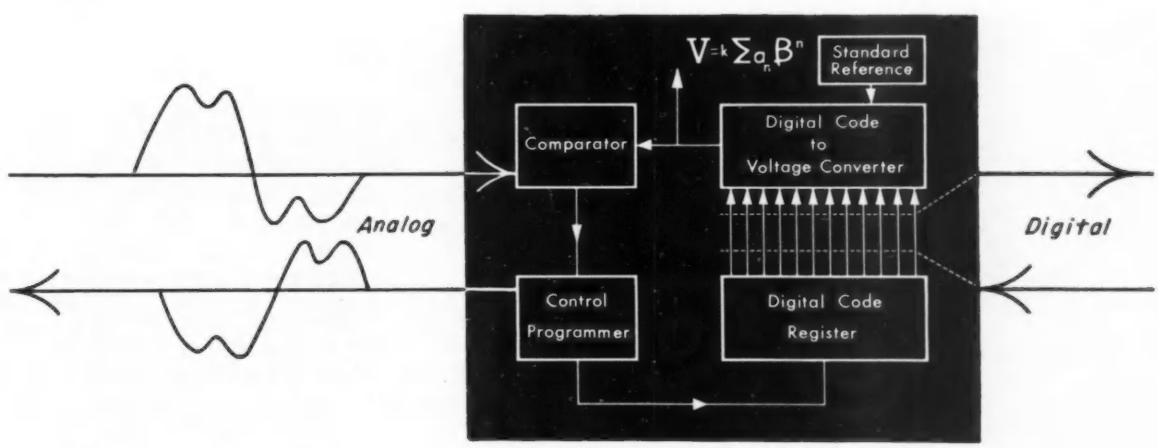
200 PRESSURES caught in a split second.

The object of this system is the instantaneous read-out of up to 200 pressures with an accuracy of one part in 2,000. Use for this is seen in wind tunnels, process systems, engine testing labs, etc.

Here's how the system works: Many air pressure inputs are led to one point and at the exact desired instant of read-out they are sealed in their lines by solenoid valves. Having bagged the many air pressures to be measured, they can now be "read in leisure". The reading process is very fast, however, and accomplished in one "sweep". All of the trapped pressures are compared with a single manifold pressure, which increases through the maximum desired range. Each trapped pressure equals the manifold pressure when a "read-out relay" associated with each is opened. The rising manifold pressure sends signals into a capacitance memory associated with each read-out relay before the relays begin operating. The value of each pressure now being in storage, each can be read in any sequence by any type of print-out device desired. One of the more unique aspects of the system is the Press-I-Cell which translates the rising manifold pressure "sweep" into pulses. Fischer & Porter Co., 356 Jacksonville Road, Hatboro, Pa.



Circle No. 2 on reply card



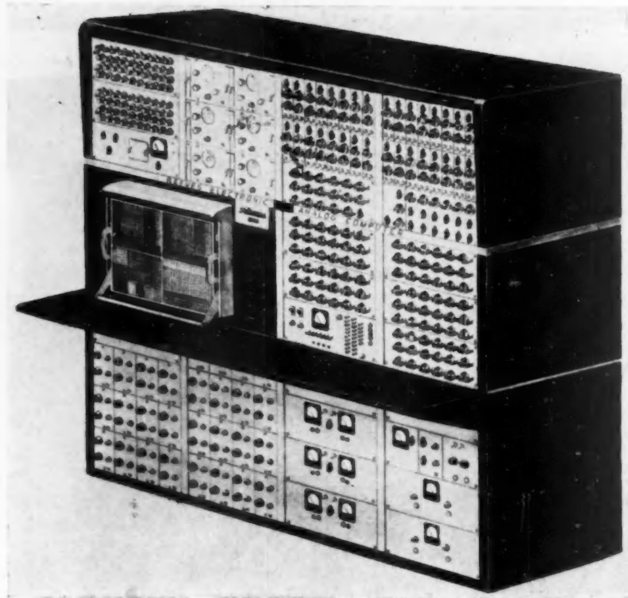
CONVERTER SYSTEM changes analog to digital and back.

With this converter system, analog inputs, such as from process pickups, can be converted to digital signals, recorded on tape or other medium, or computer manipulated, then reconverted into an analog voltage, which can be used as a control signal for an analog element.

Application of the DATRAC converter includes machine-tool control, where digitally prepared control information can be converted to continuous voltages for tool movement. In psychological measurement, it can convert slowly varying information into a visual display and accurate numerical form. Analog signals can be recorded and played back with an accuracy of one part in a million. Models are available for multiple-channel use and high speed or high accuracy emphasis. Epsco Inc., 688 Commonwealth Ave., Boston, Mass.

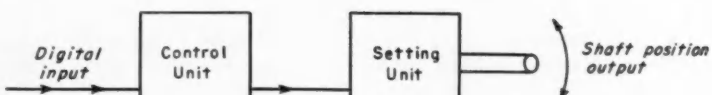
Circle No. 3 on reply card

ANALOG COMPUTER features building-block conveniences.



Put together along building-block principles, this new Reeves analog computer features a new way to verify problem solutions. Problem Check, developed by Reeves for this computer, operates directly from the problem equations and consequently verifies the operation of every component used in running, patching, and diagramming the problem from the equations. All components plug in from the front so that spares can be used to quickly replace sections which may require servicing. All routine adjustments are accomplished from the front of the panel on this "400" series REAC. *Reeves Instrument Corp., 215 E. 91st St., N. Y. 28, N. Y.*

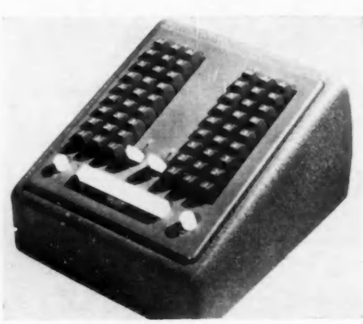
Circle No. 4 on reply card

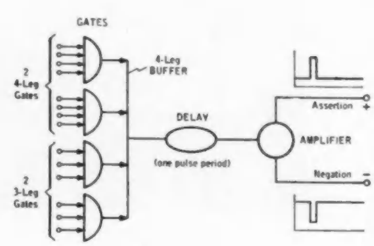


DIGITAL INPUT converts any arithmetic code to analog output.

For the manual conversion of data into X-Y voltages, three banks of precision resistors are connected to the keys of this keyboard through wiper contacts aimed at low-contact resistance without sticking. Connected to an X-Y plotter, the punched-in values of X and Y are transformed into voltages that drive the pen mechanism to the appropriate point, whereupon the pen lowers and marks a dot. Quadrant location of the point, positive or negative, is achieved by switches on the face of the keyboard, which reverse the connections of the input power, normally taken directly from the associated plotter. Librascope makes two models and a punched card converter system, too. *Librascope, Inc., Glendale, Calif.*

Circle No. 5 on reply card



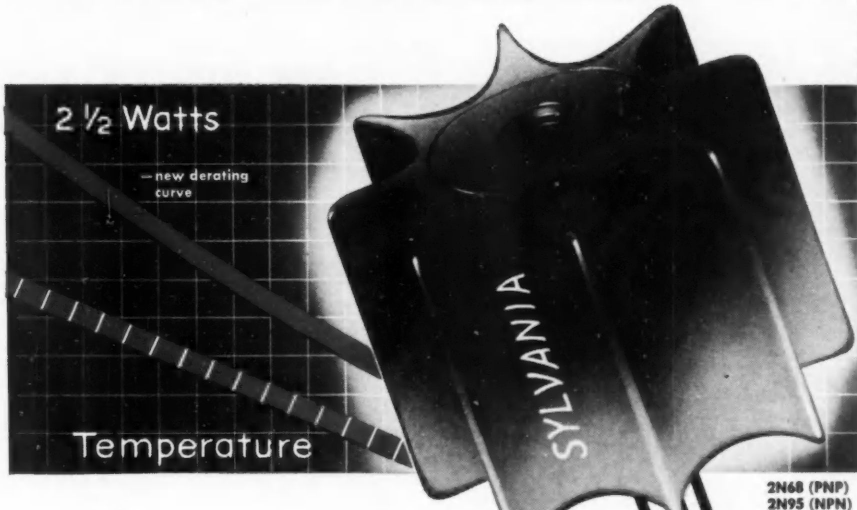


KEYBOARD VOLTAGES fed into plotter provide X-Y points.

This new device controls the angular position of a shaft from digital input. With typical speeds of 3,000 increments per sec and unlimited accuracy, it will position plotting board coordinates from a computer output, set machine tool dimensions through a lead screw or dividing head, and remotely set analog computer inputs, chemical flow valves, process control set points, or test equipment. No translator is required for any arithmetic code, and input consists of contact closures representing digital quantities. These contacts carry 1 ma from the Microsetter's power supply and may be manual switches, card or tape readers, or relays. They remain stationary during each setting operation. The unit then positions an output shaft to any number, or fraction, of revolutions specified by the input. Speed, input and output power, size, and applicability appear extremely versatile. The Microsetter has no memory element or pulse cumulator, so that if current from the control source fails, and then starts again, the Microsetter will move to the position dictated by the control unit, regardless of intervening changes. *Schatzki Engineering Company, 147-47 Springfield Lane, Springfield Gardens, Long Island, N. Y.*

Circle No. 6 on reply card

Sylvania Power Transistors...



2N68 (PNP)
2N95 (NPN)

...now with increased ratings

dissipate 2½ watts in free air, have low thermal inertia

New Sylvania design developments achieve low thermal inertia and increased ratings in the Sylvania Power Transistors 2N68 and 2N95. Dissipation of 2½ watts in free air reflects a full watt increase over previous ratings. Power dissipation up to 5 watts is possible with an external heat sink.

With Sylvania's new design heat is conducted quickly away from active elements. Resulting low thermal inertia improves performance stability over a wider range of operating temperatures. Operated as a Class A amplifier the 2N68 or 2N95 provides a minimum power gain of 20 db.

"Another reason why it pays to specify Sylvania"
Sylvania Electric Products Inc.
1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.,
University Tower Building, St. Catherine Street, Montreal, P. Q.

SYLVANIA

Sylvania Transistors — for military, industrial, and commercial applications. Available in commercial quantities.

High-Gain, Low Frequency—2N35 (NPN)—2N34 (PNP)—low to medium power—use as a high-gain audio amplifier—gains up to 40 in grounded emitter circuit.

High-Power, Low Frequency—2N68 (PNP)—2N95 (NPN) increased power ratings—use for high current, low voltage applications (6-24 volts power supplies).

High Frequency—2N94 (NPN)—2N94A (NPN)—high alpha (over 0.95)—low base resistance and collector capacitance—typically 1500 ohms uufd—gains up to 40 db.

Also available in commercial quantities

Silicon Junction Diodes—1N137A—1N138A and allied types—high back resistance at high operating temperatures.

Silicon Point-Contact Diodes—1N193, 1N194, 1N195, 1N196—specifically designed for computer and high temperature general purpose applications. Excellent transient response (0.1 u sec.)

For your semiconductor requirements, check Sylvania first. Use this convenient form to indicate your interests and address it to Department C20R.

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1740 Broadway, New York 19, N. Y.
Gentlemen: Please forward additional information on the items checked below:

Transistors	*Silicon Diodes*
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☐ High Gain	☐ Junction
☐ High Frequency	

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City____________________
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LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

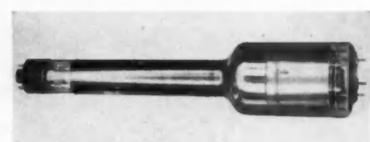
SOME UNUSUAL COMPONENTS

HIGH-SPEED SWITCHING by commutator-generator.

This precision commutator and impulse generator is designed for high-speed switching in counting, digital indication of shaft rotation, pulse shaping, pulse gating, sequence circuit control, and similar operations. The unit consists of a series of conducting segments insulated from one another and bonded to a high-temperature plastic base. These segments are interconnected to form a variety of coded commutation or pulse sequences. Multiple isolated wipers allow commutation in several circuits simultaneously and increase total pulse count per revolution. The unit can be nested with standard potentiometer elements of the same manufacturer for various analog-to-digital conversions, potentiometer excitation control, pulse shaping, and the like. The element is 1 in. diam and weighs $\frac{3}{16}$ oz. All contacts are precious metal. A life of more than 1 million revolutions is possible and speeds of up to 1,000 rpm are permissible. It is available either unmounted or mounted in a precision end bell assembly. *Computer Instruments Corp.*, 1964 *Utica Ave., Brooklyn* 34, *N. Y.*

Circle No. 7 on reply card

RECORDING TUBE can remember as many as 125,000 bits.



This recording tube is one of three that produce a variable time delay between input and output signals. Input can be stored for a week or more and then repeated up to 30,000 times. Suggested applications are with radar, sonar, computers, and high speed communications. These tubes present advantages in their "writing" speed, dynamic range, "erasing" and "priming" ease, "memory" duration, usable output repetition, and extent of storage.

An electron beam passes through a fine mesh screen, coated with storage materials on its reverse side, and strikes a collector-reflector. The beam in the Qk464 is magnetically deflected and focused with standard TV coils. During "writing" a signal-modulated beam passes through the mesh and is reflected by the negative collector-reflector back onto the coated surface. A positive charge, determined by beam current density and speed, is built up on the storage screen.

For "reading," the collector-reflector is made positive, and the storage screen voltage is dropped to a level giving uncharged areas sufficient negative voltage to cut off the electron beam. The constant current electron beam is scanned over the storage screen, and the amount of beam current reaching the collector-reflector, and developed across its load resistor, will be proportional to the charge at the scanned screen area.

The tube is "erased" by "writing" a dc signal onto it, and then "primed" by uniformly charging the storage surface. Application, operation, and performance characteristics of the group of tubes are available. *Raytheon Manufacturing Co., Waltham, Mass.*

Circle No. 8 on reply card

FEEDBACK FACT

Posed: Some way for the golfing instrument engineer to forget his job on weekends.

Solved: Have him buy Taylor's Golf Barometer. No hint of dreary fahrenheit and mercury inches here—it's calibrated strictly in fairway vernacular.

BARBER COLMAN

Barcol®

Small Motors

Now with new, improved gear reduction for radial thrust and overhanging loads

WIDE RANGE OF APPLICATIONS FOR NEW BARCOL TYPE DYAZ GEARED SMALL MOTORS

Vending Machines

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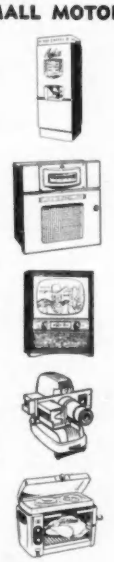
And many more



Here's a new line of Barcol geared motors designed for applications involving overhanging or radial thrust loads.

The new Barcol DYAZ open-type geared motor offers extra ruggedness, quietness, and dependability. Double-supported gear shafts run in sintered bronze bearings which are assured long-life lubrication through extra large oil wicks. Uses *heavy duty* gears and output shaft. Helical pinion and first gear step provide quieter, smoother performance. Frame plates are of anodized aluminum with four mounting bolts extending through the front plate.

This advanced type Barcol geared motor is available in gear ratios from 4:1 to 30,000:1. Starting torques up to 75 lb-in. Your choice of synchronous or non-synchronous unidirectional motors, or non-synchronous reversible motors.

Get the complete story now—write for new illustrated Bulletin F-6841 on Barcol DYAZ Geared Motors.

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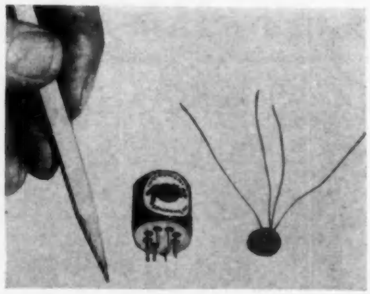
Small Motors • Automatic Controls • Industrial Instruments • Aircraft Controls • Air Distribution Products • Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

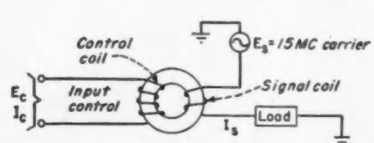
NEW PRODUCTS

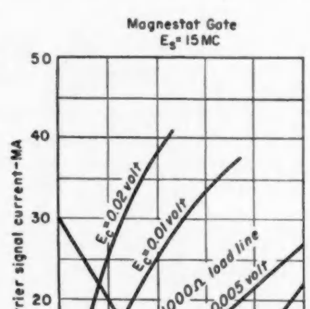


MAGNETIC ELEMENT presented as rival to transistor.

Magnetic elements, apparently with all the advantages and none of the disadvantages of transistors and magnetic cores, have been developed for various control applications. These Magnistors are small, saturable reactors with unique shapes and flux paths. Two classes are available, transient and permanent.

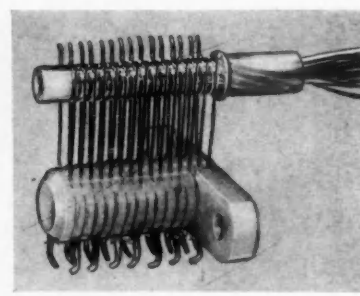
Simple transient amplifier forms contain a signal and a control winding on ferroceramic material. Impedance of the signal coil to a sine wave or pulse varies substantially as an inverse linear function of the dc control coil current. The permanent





type has an extra control winding, giving two possible impedances to the control coil, a low and a high one, each determined by the passage of a specific current in the "set" and "reset" control coils, respectively. Each impedance persists until displaced by the other, even if no current is flowing in the system. Gains of up to 500 are claimed. Units available as components or in assemblies have indefinite life. The control frequency range is from dc to 30 mc and the signal coil current from 100 kc to 15 mc. They are unaffected by temperature extremes. *Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.*

Circle No. 9 on reply card



MINIATURE slip rings and brushes custom designed.

Miniature slip rings and brushes now can be matched to the specific requirements of various computers, telemeters, and other electronic control and indicating systems. Many problems involved in the transmission of electrical energy to and from rotating elements have been eliminated in the fundamental design of these units. The manufacturer claims low friction with positive electrical contact, multiple circuits in extremely compact assemblies, high dielectric strength despite compactness, long life, and rugged construction. A four page folder containing details and drawings is available. *Iron Fireman Electronics Div., 2839 S. E. 9th Ave., Portland, Ore.*

Circle No. 10 on reply card

ANALOG TO DIGITAL with radar-type circuits.

Readings as frequent as 20 three digit numbers per sec can be made with the Model 310 Digital Voltmeter, which employs radar-type measuring circuits. Range of measurement covers 100 milliv to 999 v, accurate to one digit. *Franklin Electronics, Inc., Philadelphia 40, Pa.*

Circle No. 11 on reply card

Free! THIS BRAND NEW BOOKLET ABOUT

automatic speed control

HOW TO APPLY THE ADVANTAGES OF VARIABLE SPEED TO AUTOMATION

Typical applications of Varitrol pneumatic control regulating the speed of Varidrives in response to a signal from such variables as temperature, humidity, pressure, speed, liquid level, weight and tension are dramatically pictured and explained in this full-color booklet. How the Varitrol pneumatic system functions is illustrated with full-color cross-section drawings and diaphanous views of the U. S. Varidrive with exclusive right angle speed-changing linkage. This educational booklet, edited by variable speed engineers, is your guide to a method of greater production of more goods and services at lower cost and astounding man-hour savings. Write today for your complimentary copy.

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U. S. VARIDRIVE

WITH *VARITROL®*

FOR VARIABLE SPEED AUTOMATION

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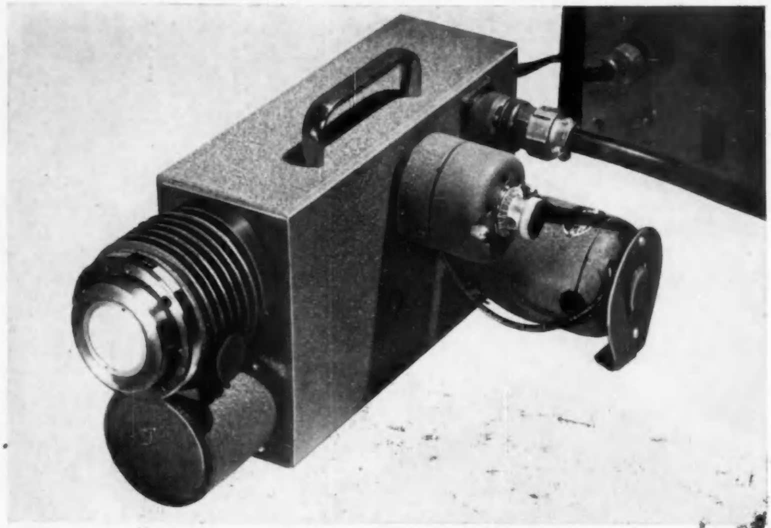
NEW PRODUCTS

A CAMERA TRANSDUCER



INTERFEROMETER AND CAMERA record fast pressure variations.

An interesting approach to a more or less universal ultra-high-accuracy motion detector is encased in this unit. Despite its small size, a camera, including a one millisec timing pip system, and a complete interferometer are built in to measure the motion of a diaphragm. Short-term pressure variations of the atmosphere or of pressure systems are indicated by the photographed fringes. However, the instrument can measure the motion of any physical phenomena, such as magnetostriction effects of a body in a magnetic field and crystal reactions to varying electric currents. Shown in the background is the control unit, which completely commands the transducer and which can be remotely located from it. *Beckman & Whitley, Inc., 805 E. San Carlos Ave., San Carlos, Calif.*

Circle No. 12 on reply card

ELECTRONICS IN CONTROL

VERSATILE is this direct-coupled amplifier.

A new model direct-coupled amplifier, this unit takes the place of specialized instruments for many applications. Designed for either rack or bench, Model D-1 incorporates a fully regulated power supply. Useful gain is 80,000 and frequency response is flat from 0 to over 100 kc at gain up to 10,000. *Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston, Texas.*

Circle No. 13 on reply card

EXTREME ACCURACY marks these delays.

Several features give accuracy of delay to the Model F-110 Tapped Delay Line that far exceeds conventional specifications for similar units. Total delay of 112 microsec, with taps every 2 microsec, is provided. Accuracy is 0.1 per cent at full delay and total rise time is less than 1.5 microsec. *Control Electronics Co., Inc., 1925 New York Ave., Huntington Station, N. Y.*

Circle No. 14 on reply card

POSITIVE DISPLACEMENT

NO STUFFING BOX

Specify Lapp Auto-pneumatic PULSAFEEDER

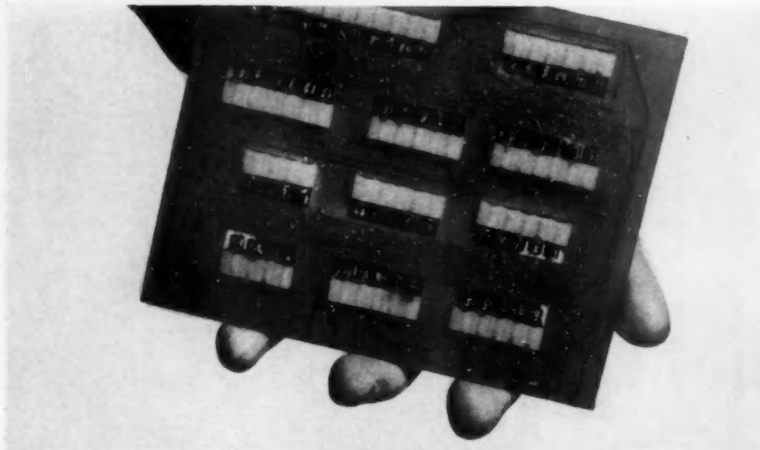
. . . for Automatically Controlled Metering of Liquids

The outstanding features of the Lapp "Auto-Pneumatic" Pulsafeeder make possible continuous automatic processing of liquids which cannot be satisfactorily handled by plunger-type metering pumps. The "Auto-Pneumatic" Pulsafeeder is a piston-diaphragm pump providing positive displacement without the problems of a stuffing box. A hydraulically balanced Pulsafeeder diaphragm isolates the product from the working parts of the pump, preventing product leakage or contamination. With pneumatic instrument control, the pumping rate of the "Auto-Pneumatic" Pulsafeeder automatically adjusts from zero to full capacity. Manually adjustable models also available.

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 392 Wilson Street, Le Roy, New York.*

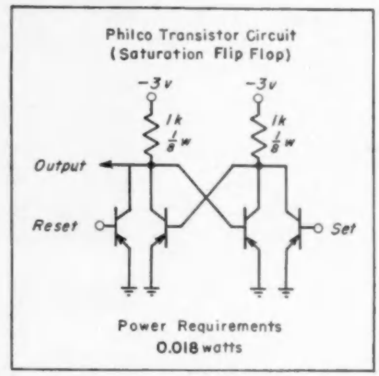
Lapp

NEW PRODUCTS



COMPUTER MODULES economically transistorized.

Using the L-5106 high frequency surface barrier transistor, Philco has come forward with "TRANSAC" digital computer modules, said to make possible mass-produced transistorized computers. The pride is the Philco Direct Coupled Circuit which handles additions and subtractions at the rate of 600,000 per sec. It will add 19 binary digits in 2.4 microsec. Power requirements are low, circuits are rapid, and all elements required for addition, subtraction, multiplication and division, as well as common control circuits, are combined on a printed circuit having only transistors and resistors. A lifetime of more than 20,000 hr is indicated in 80 per cent of early version of the L-5106. Their flip-flop is shown below. It consumes 1/1000 the power required by vacuum tube circuits. *Philco Corp., Philadelphia 44, Pa.*



Circle No. 15 on reply card

GATING PACKAGE provides endless variety.

All digital system needs may be filled with this one basic component, a new universal logical package. The units, high-speed digital building blocks, operate at a 1 mc repetition rate. The 3C-PAC gating package is useful for digital computation, control, and data handling. And the compact standardized plug-in circuits can be used to build up installations ranging from small classroom setups to large-scale industrial research and control centers. Components are mounted on an etched circuit panel 7 in. square, which is plugged into a receptacle joined to a plugboard on which jumper connections determine logical operations. Accessory equipment and design consultation available. *Computer Control Co., Inc., 92 Broad St., Wellesley 57, Mass.*

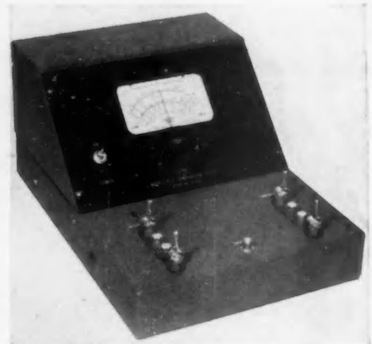
Circle No. 16 on reply card

FEEDBACK FANCY

Needed: A sure-fire way to get young engineers into the lures of servo technology.

Solved: Why not a Servo Erector Set for tots who are bored with nuts and bolts and ready for the breadboard? Gilbert Company, please note before next Xmas.

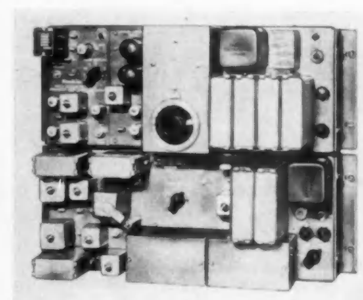
NEW PRODUCTS



NEW COMPARATOR has foot switch.

This new model comparator can be operated by an optional foot switch or conventional pushbutton. Stability, accuracy, and sensitivity have also been improved in the E-2 Comparison Bridge. *Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston, Tex.*

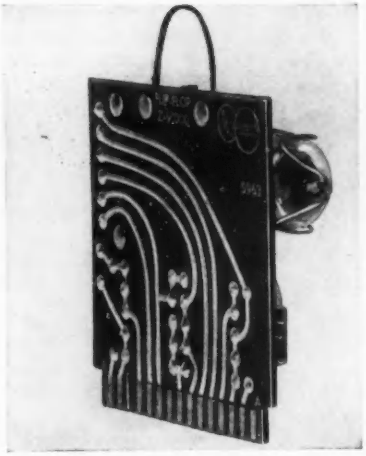
Circle No. 17 on reply card



FIRST TRANSISTORIZED commercial power line carrier.

First in commercial production, this new narrow-band frequency shift apparatus has a completely transistorized receiver and a transmitter using transistors for all but the power output stage. Power consumption is reduced up to 75 per cent, only 6 being consumed with imperceptible heating. The unit is used to transmit keyed type functions between power transmission line station and for telemetering, load control, supervisory control, teleprinting, and remote control and indication. It features channel spacing of 500 cycles through its range of 40 to 200 kc. *Motorola Communications and Electronics, Inc., Technical Information Center, 4501 W. Augusta Blvd., Chicago 51, Ill.*

Circle No. 18 on reply card



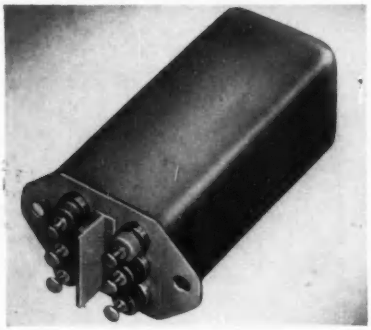
FLIP-FLOP comes in etched plug-in unit.

Counting, frequency division, switching, and time selection are possible with this new plug-in flip-flop. The unit, employing an etched circuit, is low in cost and light in weight. One Z-91000 can be directly coupled into another without amplifiers, and the flip-flop is wired for linear, binary, and feedback counting operations. It plugs into a standard 15-contact printed connector. *EECO Production Co., 827 S. Vermont Ave., Los Angeles 5, Calif.*

Characteristics

Weight.................... $1\frac{1}{2}$ oz
Size.............. $3\frac{1}{2}$ x $2\frac{3}{4}$ x $1\frac{1}{2}$ in.
Power requirements..200 vdc at 3.5 ma 6.3 or 12.6 v filament supply
Speed.....................100 kc

Circle No. 19 on reply card

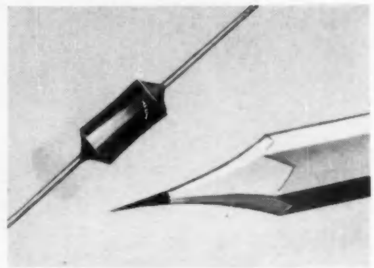


TINY CHOPPER has no moving parts.

Illumination of a photoconductive element in a typical voltage divider modulates dc to frequencies up to 400 cps in this electronic chopper. Model 307 features minus 50 to plus

100 deg C operation, 0.5 conversion ratio, less than 200 microv rms noise, and 115 v 3 ma ac excitation. It weighs 1.6 oz and is 7/8 in. high by 7/8 in. wide by 2 in. long. *Avion Instrument Corp., 299 State Highway 17, Paramus, N. J.*

Circle No. 20 on reply card

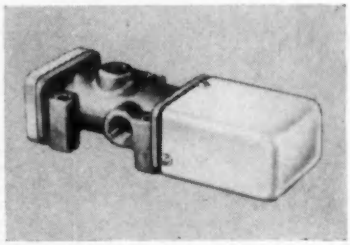


SUB-MINIATURE RESISTOR resists adverse conditions.

The characteristics of this new subminiature resistor remain unaffected by immersion in salt water, humidity, and extremes of temperature. Designed for applications where space is limited, it is 3/16 in. in diam and 7/16 in. long. The unit is precision wirewound, completely encapsulated, and has axial leads. The Davohm 1274 is available with a maximum resistance of 180,000 ohms, and it will dissipate 1/4 watt at 125 deg C without derating. Tolerances as close as plus or minus 0.02 per cent are obtainable. Additional data available. *The Daven Co., 191 Central Ave., Newark 4, N. J.*

Circle No. 21 on reply card

VALVES FOR CONTROL

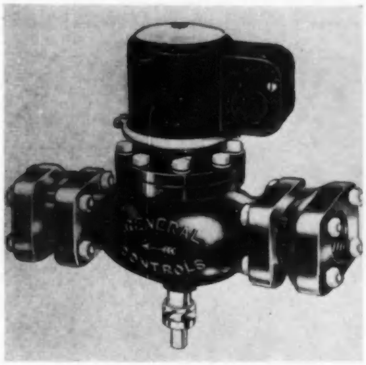


HANDS, feet, or solenoids operate 3-way valves.

Here's a series of three-way valves in the heavy-duty "Bel-Air" valve line. Sizes from 1/4 through 1/2 in. are stocked for manual or electric control by solenoids built for 115, 230,

or 440 volt operation. *The Bellows Co., Akron 9, Ohio.*

Circle No. 22 on reply card



PILOTED valve has emergency manual operation.

Magnetically piloted, this piston valve is designed for refrigerant control. Because of its piloted action, this K-15F series valve handles large capacities with a minimum pressure drop. One to 2 in. pipe sizes are accommodated. Manual operation is possible in the event of emergency current failure. *General Controls Co., Glendale 1, Calif.*

Circle No. 23 on reply card

PACKLESS valve for low pressures.

Solenoid-operated and direct-lifting for pressures up to 7 psi, this packless valve is available in ⅜ to ½ in. sizes. The only moving element is a stainless steel core and composition disk, housed in a heavy duty, forged brass body. A return spring returns the core and attached disk to a tightly

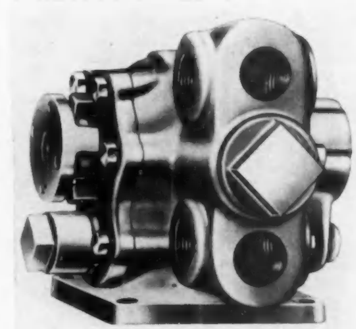
closed position when the solenoid is deenergized. Further details on this valve are obtainable in a bulletin. *Automatic Switch Co., Orange, N. J.*

Circle No. 24 on reply card

ELECTRO-PNEUMATIC valve shuts silently.

Silent operation is one salient feature of this solenoid valve. When energized, it passes full air at pressures up to 25 psi. When deenergized, the supply port is stopped and the return line pressure is wasted to atmosphere. A manual adjustment produces the converse performance. Port connections are $\frac{1}{8}$ in. NPT and 60-cycle coils can be supplied for 115, 208, 230, or 440 v. Bulletin 359 and Drawing 1255 give the details. *The Powers Regulator Co., Skokie, Ill.*

Circle No. 25 on reply card



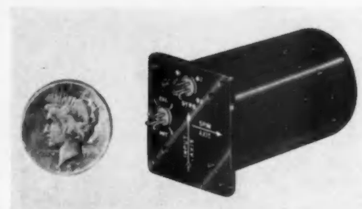
THREE cylinders positioned with this valve.

Here's a rugged, four-way rotor-actuating valve for positioning from one to three hydraulic cylinders. Known as Type 555-RO, it takes pressures in the 300 to 1,500 psi range with a capacity of 400 gpm at 1,500 psi. *A. W. Cash Co., P. O. Box 551, Decatur, Ill.*

Circle No. 26 on reply card

NEW PRODUCTS

FOUR NEW GYROS



HERMETICALLY SEALED GYRO can be damped.

Small size does not limit the high performance displayed by this damped rate gyro. Developing an angular momentum of 400,000 gm cm^2 per sec, the gyro can be damped from 0.2 critical to over damped through minus 55 to 80 deg C without a heater. *Instrument Div., R. C. Allen Business Machines, Inc., Grand Rapids, Mich.*

Circle No. 27 on reply card

HIGH ACCURACY under extreme conditions.

Entirely new caging and manufacturing methods are said to give this Model 45,000 gyro high accuracy under extremes of vibration, temperature, acceleration, and shock. Minimum service life is 1,000 hours. Normal drift rate is 6 deg per hour and drift during vibration, up to 2,000 cps at 10 G, is less than plus or minus 30 deg per hour. *Gyromechanisms, Inc., Halesite, N. Y.*

Circle No. 28 on reply card

NEW AMOUNT GYRO for attitude control.

The CG-100 is designed for controlling attitude of aircraft and guided missiles under moderate to heavy vibration and steady state accelerations. It has separate synchro pickups and a dc solenoid-operated caging mechanism. *Automatic Controls Div., Clary Multiplier Corp., San Gabriel, Calif.*

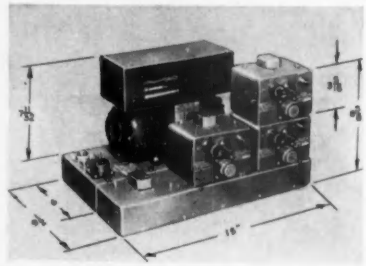
Circle No. 29 on reply card

STEEL PARTS kill differential expansion.

Variations in free drift resulting from ambient temperature changes have been eliminated in this all-steel gyro. With the Series 2153 Vertical Gyro, predictable free drift remains uniform through its temperature range. Other friction reducing features give a three-fold improvement in friction-to-momentum ratio. Angular momentum is 8,000,000 gm cm^2 per sec, spin axis can be maintained within $\frac{1}{10}$ deg, and drift error is less than 0.25 deg per min. *Lear, Inc., Dept. 80, 110 Iona, N.W., Grand Rapids, Mich.*

Circle No. 30 on reply card

POWER SUPPLIES



POWER PLUS demodulation in one package.

This package supplies regulated 400-cycle power for flight instruments and demodulates 400-cycle signals for magnetic oscillograph recording from synchro-type pickups. The power input is 26 to 29 vdc at 23 amp, and the output is 110, 26, or 10 v, 400 cps. The demodulator input is 10 micro-watts, 400 cps; the output, 600 micro-amp at 200 ohms. *Dynalysis Development Laboratories, Inc., 11941 Wilshire Blvd., Los Angeles 25, Calif.*

Characteristics

Weight	8 oz
Size	1¼ in. diam
Power Rating	½ watt at 160 deg F
Life	1 million cycles

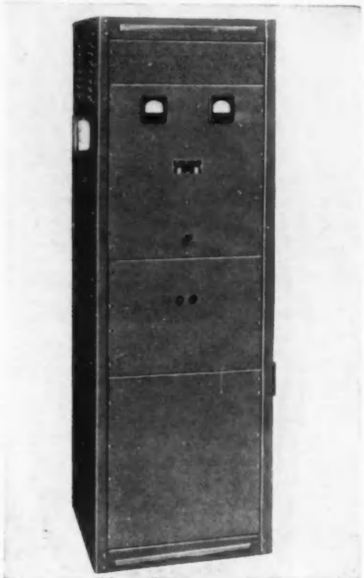
Circle No. 31 on reply card

INDEPENDENT OUTPUTS from this power supply.

This power supply has two independent high voltage output ranges. The unit delivers 0-300 vdc at 300 ma, 0-300 vdc at 150 ma, variable bias 0-150 vdc at 5 ma, regulated by VR tube, and 0-10 vac, unregulated at 10 amp max variable with powerstat. Output voltages change 0.15 per cent for line voltage of 115 vac plus or minus 10 per cent, with less than 30 mv change from no load to full load. Ripple is less than 5,000 microvolts.

rms. Both positive and negative of either output may be grounded on this model D3-300D. *Dressen-Barnes Corp., 250 N. Vinedo Ave., Pasadena 8, Calif.*

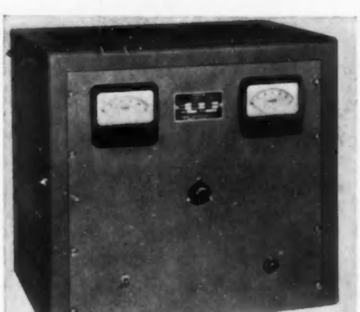
Circle No. 32 on reply card



25 KW from tubeless rectifier.

This new 25 kw, 230 vdc rectifier power supply operates from 230 v, 60-cycle, three-phase ac input. Voltage regulation is 15 per cent with a max ripple of 5 per cent. A new Perkin unit, it measures 18 in. wide by 22 in. deep by 72 in high. *Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.*

Circle No. 33 on reply card



COMPACT AND LIGHT germanium rectifier.

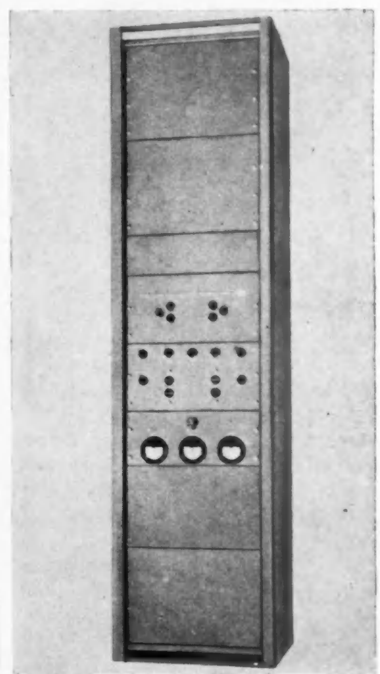
This tubeless germanium rectifier weighs only 125 lb. and stands 22 in. wide by 15 in. deep by 19 in. high.

This model G 125-25, convection cooled, is recommended for use in laboratories and plants requiring an economical and compact unit. *Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.*

Characteristics

Output . . . . 125 vdc, 25 amp
Input . . . . 230 vac, 60 cycle, 3 phase
Voltage Regulation . . 4 per cent no load to full load, 1½ per cent from ½ rated load to full load
Ripple . . . . 5 per cent rms
Efficiency . . . . 94 per cent
Power Factor . . . . 98 per cent

Circle No. 34 on reply card



ANALOG COMPUTER power supply.

The two output voltages of this power supply, designed for use with analog computers, are maintained within 0.02 per cent of their absolute voltage value and both outputs are inter-referenced to plus or minus 0.01 per cent. Long time stability is over 100 parts per million and short time stability over 50. Each output is plus or minus 100 v at 2 amp, ripple and noise less than 1 mv, and output impedance less than 0.01 ohm for dc and less than 0.5 ohm for ac up to 200 kc. Line regulation is plus or

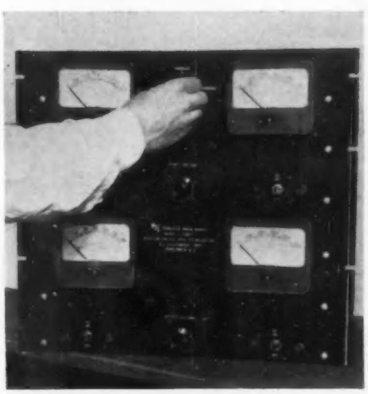
minus 0.01 per cent for plus or minus 10 per cent change. Other voltage and current ranges available. *Kay Lab, 5725 Kearny Villa Rd., San Diego, Calif.*

Circle No. 35 on reply card

ONE KNOB controls output of power unit.

The 0-35 vdc, 15 amp continuous, 20 amp intermittent, output of this compact, portable power supply is continuously variable through operation of one knob. Ripple is less than 1½ per cent at 15 amp output with the KS-2903. *Kell-Strom Tool Co., Inc., Wethersfield, Conn.*

Circle No. 36 on reply card

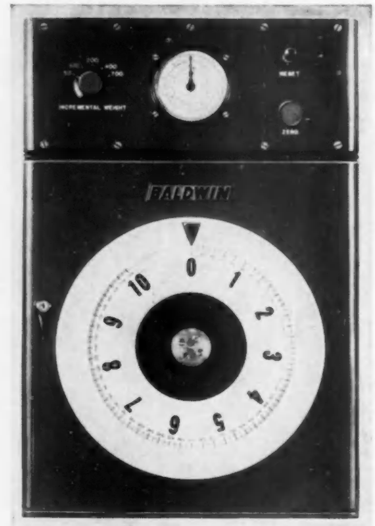


FOUR WAY SWITCHING on dual power supply.

Two heavy-duty power supplies, each 200-300 v at 0-300 ma, can be used for series aiding (400-1,000 v, 0-300 ma), in parallel (200-500 v, 0-600 ma), for series bucking (0-300 v, 0-300 ma), or can be isolated by a unique, front panel switching arrangement. Grounding of either polarity is possible with all arrangements. Seven other dual units are available. *New Jersey Electronics Corp., 345 Carnegie Ave., Kenilworth, N. J.*

Circle No. 37 on reply card

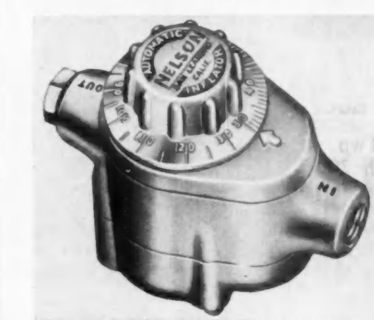
PROCESS CONTROLERS



FLOW RATE measured through time and weight.

.. Here is the way this flowmeter works: its input is a weight cell with 1,000 pound capacity located so as to measure the weight of a tank into which a liquid is flowing. The meter is zeroed on the empty weight of the tank, and a timer used to note the time required for a pre-set increment of the liquid to enter the tank. The result is an indication of flow rate. Incremental weights ranging from 50 to 700 lb are possible, permitting a wide range of flow rates to be checked with the instrument. *Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.*

Circle No. 38 on reply card



PRESSURE regulated by dial setting.

Pressure regulation through a simple dial setting is the special feature of this item. Two standard models

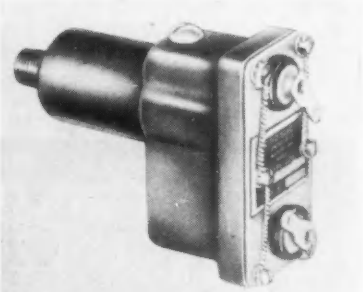
are available, one with 15 to 45 psi range, the other 10 to 110 psi. Special ranges are available on order. *Barmotive Products Inc., 440 Peralta St., San Leandro, Calif.*

Circle No. 39 on reply card

MANUALLY balanced, shows temperature differences.

Useful for measuring temperature differences as small as 0.02 deg. F, this manual-balance indicator is recommended for heat exchangers, distillation columns, wet and dry bulb humidity measurement, etc., through the use of two resistance bulbs connected opposed to each other. *Thermo Electric Co., Inc., Saddle River Township, Rochelle Park post office, New Jersey.*

Circle No. 40 on reply card

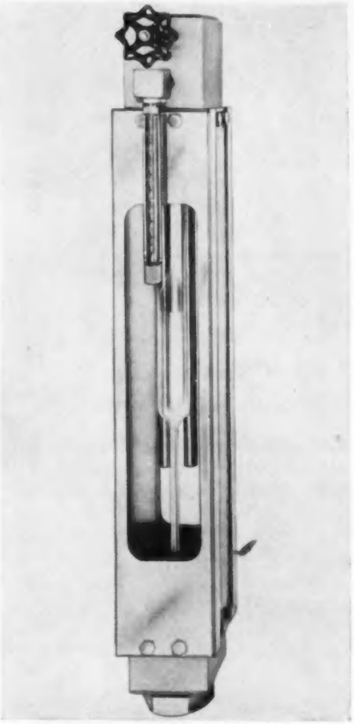


SWITCH operates on absolute pressure changes.

Action anywhere in the range of 0 to 35 psi with a differential choice between 1.5 and 5 psi occurs independent of atmospheric pressure with this Type J20 pressure-operated switch, as it uses completely evacuated bellows. Altitudes of up to 60,000 feet and 100 per cent relative

humidity do not affect its operation. *United Electric Controls Co., 85 School St., Watertown, Mass.*

Circle No. 41 on reply card



SPECIFIC GRAVITY measured rapidly, accurately.

Liquid densities can be measured conveniently for continuous sampling and other processing services with this specific gravity indicator. The unit employs a nonspin hydrometer in a special enclosure with safety glass and side plate construction. Dowel pin construction allows for easy disassembly and assembly. The Spec Gee, as it is called, is available in a variety of materials such as steel, brass, 316 stn. steel, Hast. "C," and Durimet.

The unit illustrated is equipped with a built-in thermometer and needle valve as additional equipment. The liquid, controlled by the valve, flows past the thermometer, filling a Pyrex tube containing the hydrometer. It then spills into two metal overflow tubes leading to the outlet. The hydrometer is furnished with a special lug that prevents it from rotating, thus keeping it in position for easy reading. The indicator also comes with a dial-type thermometer or without thermometer and valve. *Brooks Rotameter Co., Lansdale, Pa.*

Circle No. 42 on reply card

NEW PRODUCTS

UP TO NINE circuits timed with programmer.

For complex batch processes this new timed-program controller will provide up to 20 on-and-off steps for up to nine electric or pneumatic functions. Easily set and altered time sequences are featured. Bulletin 98350 fully describes the instrument. *Taylor Instrument Cos., Rochester 1, N. Y.*

Circle No. 43 on reply card

COUNTING DEVICES

LOW COST decade counts to a million.

Printed circuits and a miniature high-speed mechanical register contribute to the low cost and simple operation of this Model 345 Decade Counter. Pulses of up to 200 cps with a trigger input of 2.5 v are summed to a million Pulse pair resolution is 5 microsec. Input impedance one megohm, weight 7 lb. Photocell and magnetic pickups are available. *Daytronic Corp., 216 S. Main St., Dayton 2, Ohio*

Circle No. 44 on reply card

ELAPSED time read to 0.1 microsec.

A temperature-controlled 10 mc crystal oscillator serves as a time base accurate to part in a million for a high-speed counter-chronograph intended for the accurate measurement of small elapsed time and pulse widths. Called the model 800, it measures intervals as long as 1/20th sec to an accuracy of within 0.1 microsec. *Electrical and Physical Instrument Corp., 42-19 27th St., Long Island City 1, N. Y.*

Circle No. 45 on reply card

MORE SPEED AND LIFE with new pulse counter.

A unique stepping motor having only one moving part gives a counting rate of 0 to 130 counts per sec through a life of 500 million counts to the Sigma Cyclonome. Minimum pulse or half cycle duration that can be counted is 3 millisec. *Sigma Instruments, Inc., 77 Pearl St., S. Braintree, Boston 85, Mass.*

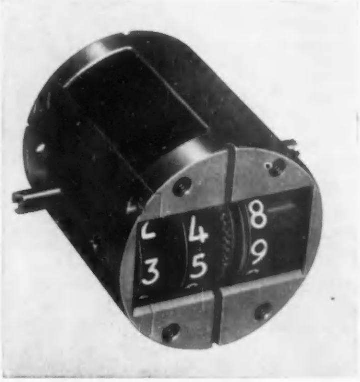
Circle No. 46 on reply card

UNSKILLED HANDS operate frequency counter.

This new direct digital reading fre-

quency counter is designed for measurement of any electrical, mechanical, or optical phenomena convertible to varying voltage. Featuring high accuracy, the DS-6100-T will operate from 1 to 100,000 events per sec. *Computer-Measurement Div., Detectron Corp., 5528 Vineland Ave., N. Hollywood, Calif.*

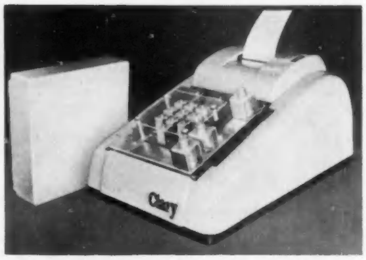
Circle No. 47 on reply card



DEGREE COUNTER turns fast and durably.

Indicating revolutions up to 359 deg, this model 1502 angle counter shows 10 deg changes for one revolution of the input shaft. Speeds of 500 rpm are attainable with the 2½ oz counter. *Bowmar Instrument Corp., 2415 Pennsylvania St., Fort Wayne, Ind.*

Circle No. 48 on reply card



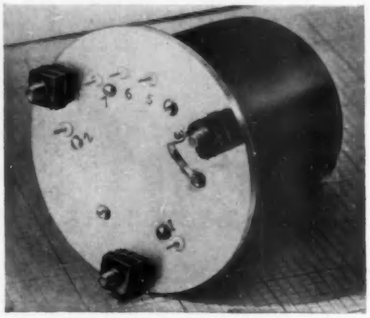
LOW COST digital read-out is speedy printer.

Eight or ten digits are printed out by this instrument as fast as 40 millisec apart (25 cps). Models 1972 and 1973 provide credit balance accumulation. Actuating solenoids are provided for 48 vdc or 110 vac or dc. The unit will accept serial information without switching from column to column. *Technical Sales Dept., Clary Multiplier Corp., San Gabriel, Calif.*

Circle No. 49 on reply card

NEW PRODUCTS

POTS AND PICKUPS



NO WAVE DISTORTION over wide range.

A new principle of design in the type PD-2 dielectric potentiometer gives an output wave form identical to the input wave over a range of frequencies from 20 cycles to 10 megacycles. Variations in input impedance, range of attenuation, adaptation to specific nonlinear functions, and mechanical drive make for varied applications. *Technology Instrument Corp., Acton, Mass.*

Circle No. 50 on reply card

50-TURN TRANSDUCER performs Kelvin-Varley functions.

The unique design of the Diviac Model 25A incorporates a system that automatically performs the functions of a Kelvin-Varley circuit. The apparatus presents a constant input im-

pedance, and input voltage is twice divided into ten equal steps—once to produce 10 per cent of applied voltage and again to produce 1 per cent of applied voltage by two banks of precision matched resistors. Further interpolation of this voltage is obtained with a precision single turn potentiometer. Switching points are uncritical and maximum input speed is 3,000 rpm as there are no genevas or intermittent drives. A smaller model, the 5A, is available that rotates through 5 turns and has only one bank of resistors, with total resistance options of 1,000, 10,000, or 100,000 ohms. *Feedback Controls, Inc., Alexandria, Va.*

Characteristics (Model 25A)

No mechanical stop	continuous rotation
Moment of inertia	1.15 gm-cm^2
Starting torque	0.4 in.-oz (max)
Linearity	(std.) 0.005 per cent absolute, zero based
Resolution	0.0005 per cent
Frequency	dc to 50 kc
Watts	10
Relay power	24 vdc at 40 ma

Circle No. **51** on reply card

DUAL ELEMENT transducer for high output.

Two metal bellows respond to pressure variations and actuate two sets of paired precision potentiometers in this differential pressure transducer. One bellows connects to the dynamic pickup line and the other to static or ambient pickup. Each of the four pots has individual outside terminals. *Technology Instrument Corp., Acton, Mass.*

Characteristics

Resistance ratio versus pressures	0.5 per cent linear
Hysteresis	0.5 per cent

NEW PRODUCTS

Temperature variation . . less than 0.5 per cent (−55 to +71 deg C)
Resolution . . less than 0.2 per cent of pressure range
Size . . $2\frac{7}{8}$ x $4\frac{3}{8}$ x $5\frac{7}{8}$ in., 1.3 lb

Circle No. 52 on reply card

PRESSURE pickup responds to transients.

A resistance-type high pressure pickup for rapid transients can be used with gas and liquids. It is available in 1,000 to 5,000 psi gage and absolute ranges, with other ranges on special order. Size is less than $\frac{3}{4}$ in diam and 1 in. long. *Consolidated Engineering Corp., Pasadena, Calif.*

Circle No. 53 on reply card

3/16 IN. HIGH and 25,000 ohms wide.

Weighing only 2 grains Tiny Trim is half the size of existing trimming potentiometers. Flat and with the adjusting screw on the narrow edge, it can be stacked in compact banks. Adjustment ratio is 80 to 1 and it is moisture and corrosion resistant, as well as stable up to 250 deg. F. *Daystrom Potentiometer, 1509 Colorado Blvd., Santa Monica, Calif.*

Circle No. 54 on reply card

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(64) COUNTERS. Richardson Scale Co. Reference sheet, 4 pp. Describes 11 counters: motor driven, mechanically tripped, ticket-printing, solenoid operating, etc.

(65) LINEAR POTENTIOMETERS. Benson-Lehner Corp. Data sheets, 4 pp. Provides pertinent dimensions and electrical characteristics for lineal-motion potentiometers with stroke lengths up to 20 in.

(66) PINCH VALVES. RKL Valve & Mfg. Co. Cat. 1154, 8 pp. Performance curves and significant dimensions of air-operated self-supporting pinch-valves for corrosive materials or abrasive slurries, wet or dry. Sizes from ¼ in. to 1 in., for line pressures of up to 100 psi.

(67) POWER SUPPLIES. New Jersey Electronics Corp. Catalog, 8 pp. Defines "line regulation," "long term stability," "internal impedance," "hum," "ripple," "noise," "bounce" for their full line of 64 power supplies, resulting from two circuits and variations of eight basic ranges.

(68) CABINETS. Premier Metal Products Co. Catalog 550, 16 pp. Tabbed for easy reference, this lists 450 standard stock metal housings for electronic gear.

(69) DIGITAL INSTRUMENTATION. G. M. Giannini & Co., Inc. File of leaflets, 16 pp. General description and application of instrumentation systems, encoder systems, data handling systems, etc. Block diagrams, specifications, and dimensions of pertinent elements are provided.

(70) LIQUID LEVEL. Minneapolis-Honeywell Regulator Co. Bulletin 1161, 20 pp. A discussion of the principles of measuring liquid level, its automatic control, tabulation, and a variety of pressure systems. A rounded little text on the subject, providing breadth and basic information, with tables and statistics.

(71) PNEUMATIC CONTROL. Minneapolis-Honeywell Regulator Co. Bulletin 1120, 44 pp. This book's 11 chapters range from the modes of pneumatic controllers to the provision of sources of clean air for pneumatic systems. A real treatise, with tables, diagrams, and curves.

(72) VALVES. Imperial Brass Mfg. Co., Bulletin 3037, 11 pp. Needle valves, toggle valves, plug-type valves, test valves, quick-disconnect valves, blow-down valves, and packless diaphragm valves are described and dimensioned in this informative piece. Sizes up to ¼ in. pipe thread are stocked.

(73) VALVE RATINGS. Black, Sivalls & Bryson, Inc., Product Information Dept. BS&B Controls Sizing Manual. Description of a new method of sizing controls through graphic analysis of predicting the action of liquids, steam, or gases for all conditions of flow. It indicates what a valve must do in a given installation, and what it will do.

(74) SHAPED WIRE. American Chain & Cable Co., Inc. Booklet DH-1226, 16 pp. Wire shaped in rounds, triangles, keystones, full ovals, half ovals, half rounds, etc., with cross-sectional areas up to and including ¼ in. square, and widths up to ¾ in. The wire is made in stainless, low and high carbon.

(75) FLAT CAPACITORS. Gudeman Co. Bulletin 337-8, 6 pp. Illustrates and gives complete technical details on miniature flat "Mylar" dielectric capacitors. Included are tables of capacitance values and voltage ratings, dimensional drawings, ex-

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planation of catalog numbers and a host of operational data ranging from lead pull tests to lead bending tests.

(76) HOSE. J. N. Fauver Co. Catalog 55, 24 pp. Hose assemblies, stems, swivels, couplings, and accessories with complete engineering data. Sizes range from $\frac{3}{16}$ in. I.D. to 2 in. I.D.

(77) PROCESS INSTRUMENTS. National Instrument Laboratories. Bulletin 153, 4 pp., outlines an accurate gas flow measurement instrument. Performance curves and detailed specifications provided. Bulletin 154, 2 pp., describes a linear flowmeter designed for accurate and convenient metering of flow rates of gases up to 20 psig. This company also makes a precision manometer and surface tensiometer.

(78) CLUTCHES. Electronic Mfg. Engineering Co. Catalog, 8 pp. Describes and dimensions a line of miniature magnetic clutches for torques up to 15 oz in. at speeds up to 200 rpm, with coil voltages from 6 to 30 dc. Single and multi-turn models are described. These clutches are under one in. in diam.

(79) TRANSFORMERS. Freed Transformer Co., Inc. Catalog 545, 24 pp. A complete catalog of transformers and magnetic amplifiers. Includes high Q reactors, high fidelity components, pulse transformers, filter chokes, toroidal inductors, etc.

(80) TACHOMETERS. Electric Tachometer Corp. Bulletin 531, 16 pp. A heavy duty electric tach with dc output for meter indication of speeds up to 30,000 rpm. Seven types of panel indicators with scale lengths up to 17½ in. are described.

(81) POWER SUPPLIES. Lambda Electronics Corp. Catalog 55, 26 pp. Regulated and unregulated power supplies, portable and rack mounted, are described in detail herein. Over 112 models to choose from.

(82) RADIATION MEASUREMENT. Tracerlab Inc. Catalog D, 111 pp. A comprehensive list of radiation instruments. Scalers, ratemeters, sample holders, survey meters, protection devices, Geiger-Mueller tubes, reference sources, scintillation, sample preparation, and safety equipment, and medical, industrial, and custom devices.

(83) SEALLESS PUMP. Chempump Corp. Bulletin 1010, 16 pp. Centrifugal pumps, seal-less and leakproof, in a range from ⅛ to 7½ hp providing head up to 195 ft and capacities to 250 gpm are shown in detail, with all relevant data.

(84) EDDY-CURRENT BRAKES. Eaton Mfg. Co. Bulletin BR-1, 12 pp. The construction and performance of brakes having no friction surfaces, cooled by either air or liquids for torques over 200 lb ft at speeds up to 1,800 rpm. These brakes, electrically controlled, described in detail.

(85) STANDARD RESISTORS. Leeds & Northrup Co. Data sheet EB2(1), 4 pp. Describes fixed dc and ac resistors.

(86) DYNAMIC MOTORS. Reliance Electric & Engineering Co. Bulletin, 12 pp. Provides information on acceleration rates, enclosures, dimensions, and selection data on a line of dc motors designed for dynamic response.

(87) ROTARY SOLENOIDS. G. H. Leland Inc. Revision 4, 26 pp. Design data: dimensions, torque, speed, driving voltage, resistance, etc., for a line of compact rotary solenoids.

(88) ELECTRONIC COMPONENTS. Electro-Measurements, Inc. Catalog, 8 pp. Descriptions and specifications of Dekastats with direct reading coaxial dial, laboratory instruments in the Deka line, and their prices.

(89) FLOW METERS. Brooks Rotameter Co. Bulletin, 20 pp. Flow capacity charts, details of design and construction, tube float material and design data, dimensional drawings, modifications, and accessory equipment illustrated, for Full-View Rotameters.

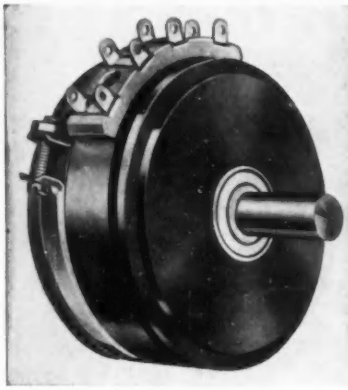
(90) PNEUMATIC PROGRAM. B.I.F. Industries. Sup. Bulletin 285-L1, 2 pp. Describes the performance, dimensions and characteristics of a cam-type pneumatic program used with chlorinizer systems, chemical feeders, or pneumatic process control systems.

(91) METAL FILM RESISTOR. Daven Co. Brochure, 6 pp. Describes Series 850 resistors. Hermetically sealed with temperature coefficients independent of resistance value, they are available up to 2 watts with tolerances to ¼ of one per cent.

(92) ROTARY ACTUATORS. New Providence Electric Co. Operational characteristics of a rotary actuator using two clutches to obtain reversible rotation and high torque from an input rotation.

(93) COMBUSTION CONTROL. Hagan Corp. Bulletin MSA-116, 14 pp. Combustion controls systems used with gas-fired boilers presented photographically. Deals with simplest natural-draft boiler using parallel control system to the very large boilers needing three-element feed water control equipment and interlocking safety devices.

(94) VOLTAGE REGULATORS. Sorensen & Co., Inc. Bulletin, 4 pp. Output curves and specifications of a complete line of voltage regulators providing accuracy within 0.01 per cent.



25 ON A SHAFT makes up this gang.

As many as 25 of the Series V Helipots may be ganged on a common shaft during manufacture. In addition, 13 tap connections can be added to each pot by spot welding each tap to a single turn of wire. Designed especially for nonlinear requirements, resistance up to 130,000 ohms are available. *Helipot Corp.*, 916 Meridian Ave., So. Pasadena, Calif.

Circle No. 55 on reply card

DO IT YOURSELF reaches dual-concentric pots.

A total of 22 controls can be built from the 363 possible combinations with the new Centralab "Fastach" dual-concentric control kit. Combinations include resistance, taper, and switch or plain types. The unit comes in a metal cabinet and is designed for engineers and labs doing experimental or pilot model work. *Centralab*, 900 East Keefe Ave., Dept. B-52, Milwaukee 1, Wis.

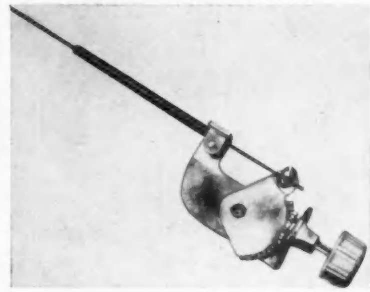
Circle No. 56 on reply card

FEEDBACK FACT

Posed: Micro-switches, like cheese, need aging before use. Engineers ask: Where is the ideal place?
Solved: Honeywell's M-S Division looked around and found the logical answer—a cheese aging room in a local dairy.

NEW PRODUCTS

CONTROL MISCELLANY



PUSH-PULL control mounts easily, flexibly.

Rotating the knob of this actuator 270 deg produces a 1½ in. linear motion of its flexible wire control. Mounting takes one nut. The mechanism behind the panel is 2½ in. deep. Intended for air-conditioners and automobiles, it nevertheless looks economical and suitable for a variety of push-pull actuation applications. Its advantages are simple, neat mounting and location flexibility provided by the wire control cable. *Arens Controls, Inc., 2017 Greenleaf St., Evanston, Ill.*

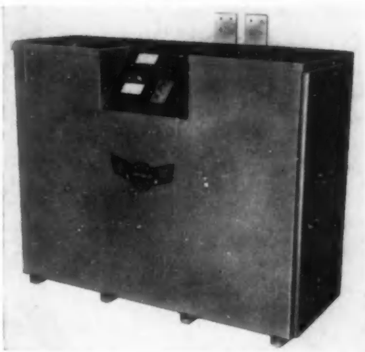
Circle No. 7 on reply card

LOW-COST PREAMP for industrial uses.

Small and low-cost, this preamplifier may be used to boost voltage of low-output transducer, or as an all-purpose laboratory type voltage amplifier. Weighing 4 lb, model 3400-A packs a gain of more than 200 up to

30,000 cps, 100 at 100,000 cps, and 50 at 200,000 cps. Peak-to-peak output is up to 10 v with less than 2½ per cent distortion, and noise at maximum gain is 40 db below the 10 v output. *Electro Products Laboratories, 4503 N. Ravenswood Ave., Chicago 40, Ill.*

Circle No. 58 on reply card



95 PER CENT EFFICIENCY from germanium rectifiers.

This new germanium rectifier, available in models from 300 to 50,000 amp dc output, gives 95 per cent efficiency at full load. Voltage variations less than plus or minus 1 volt have been maintained from no load to full load in stabilization tests. Inductor controls are oil immersed, fully motorized, and continously variable, and the elimination of fans and cooling systems results in a physically smaller, almost completely sealed unit. *Rapid Electric Co., 2881 Middletown Rd., Bronx 61, N. Y.*

Circle No. 59 on reply card

NEW LEVER for variable speed transmission.

The motion of a lever through a 180-deg arc provides variable speed control on the Speed-Trol variable speed transmission. The manufacturer offers a variety of mountings and control mechanisms with Speed-Trol to facilitate its use with conveyors, power tools, pneumatic systems, etc. *Sterling Electric Motors, Inc., 5401 Telegraph Road, Los Angeles 22, Calif.*

Circle No. 60 on reply card

NEW BOOKS

Takes the Strain Off You

The Strain Gage Primer. C. C. Perry and H. R. Lissner, Wayne University, 6 by 9 in., 281 pp. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd Street, New York 36, N. Y. $6.00.

The first half of this book covers the three basic steps in experimental stress analysis with strain gages: selection of an appropriate gage and its cementing, properly oriented, in the correct location; use of suitable instruments for measurement in each application; interpretation of the strains and their translation into stresses.

In the remainder of the book basic principles are extended to special applications. Moisture-proofing for high humidity to submersion is discussed, as are problems of long-time strain gage applications, such as zero-drift and cement- and indicator-instability, which get a chapter by themselves.

Other chapters deal with the use of slip rings and switch contacts in strain gage circuits, transducer applications, special problems and techniques (such as high-temperature strain measurement), and strain indication with brittle coatings.

The chapter on transducers describes circuitry and application of load cells, accelerometers, pressure pickups, and displacement indicators.

Spectroscopists See This

Molecular Vibration. *E. Bright Wilson, Jr., Harvard University, J. C. Decius, Oregon State College, and Paul C. Cross, University of Washington, 6 by 9 in., 388 pp. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd Street, New York 36, N. Y. $8.50.*

This work covers thoroughly the theory of the vibrations of polyatomic molecules and the application of this theory to the interpretation of infrared and Raman spectra. The theory is developed from its simplest form and advanced to the more elaborate theorems useful in complex applications.

Mathematics is at the graduate level. The text explains some powerful new techniques, such as matrix algebra and group theory. The derivations are complete and prepare the student not only to use the technique in analysis, but

to adapt them to new problems.

This is the only book in this field suitable for use as a text. It includes a thorough presentation of many techniques which have hitherto appeared only as scattered references in the scientific literature.

Sound Transistor Principles

TRANSISTOR AUDIO AMPLIFIERS. *Richard F. Shea, General Electric Co., Syracuse, New York, 6 by 9 in., 219 pp. Published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. $6.50.*

Written for the engineer familiar with vacuum tube circuits but who views the application of transistors with trepidation, this book presents the fundamentals of transistor application in audio amplifier circuits. Some network theory is included preliminary to specific design material.

Mathematical treatment is kept fairly light throughout to make the book still more palatable. Many references and a generous bibliography are included, however, for those who would investigate any phase of the work more deeply.

Chapter titles include: Fundamental Considerations; Transistor Parameters; Basic Amplifier Design; Coupled Stages; Preamplifiers; Class A Power Amplifiers; Class B Power Amplifiers; and Examples of Practical Amplifier Design.

The chapter on transistor parameters includes data on the variation of parameters with operating point, with temperature, and between units. These data are interpreted in terms of variations in input and output resistances and power gain, to make the reader fully aware of the limitations imposed by these variable factors.

The same chapter includes a 50-page "handbook" of characteristics of 22 transistor types made by five manufacturers. These specifications are so presented as to be used readily with the design methods described.

FEEDBACK FACT

Posed: Some way to automate lingerie.

Solved: Lovable Brassiere Company is doing it with some special electronic trimming devices which it has rigged up on a bevy of Singer Sewing Machines.

continued from page 11

DR. NICOLAI MINORSKY

pioneered control theory

The success of the trials, gratifying in itself, confirmed Dr. Minorsky's theoretical conclusions on two extremely significant points:

► The analysis of small oscillations gave sufficiently correct insight into the physical manifestation of higher time-derivative control actions.

► It became possible to approach rationally the quantitative analysis of control problems.

The same considerations were applied later (1938-1940) by him to the control problem of anti-rolling stabilization of a destroyer. Although this work passed successfully through a series of preliminary tests, he could not complete it because of the war. Thwarted by unpredictable Navy decisions, he has since concentrated on the theory of non-linear oscillations.

For his work as Special Consultant and Assistant to Technical Director, David Taylor Model Basin (1940-1946), the Navy gave Dr. Minorsky the Meritorious Civilian Service Award in 1946. His book, "Introduction to Non-Linear Mechanics," was published the same year. Following this, he became a professor at Stanford University and supervisor of the non-linear mechanics project under the authority of the Office of Naval Research. During this period he investigated further the theory of parasitic oscillations in control systems on the basis of difference-differential equations. These theoretical predictions found experimental confirmation by means of an electronic analog he built and were also later confirmed by wind tunnel tests.

His health affected by many years of strenuous work, he and his wife retired in 1949 to their old farm at Aix-en-Provence, France. Since then, Lear, Inc. has retained him as a consulting physicist in connection with flight controls and servos.

Under contract to Stanford University, he is preparing the second edition of his 1946 book on the theory of non-linear oscillations. Of it he says, "This is a gigantic task, as in these 7-8 years science has made such huge progress that in many chapters one has to start 'from a scratch.' However, about 300 pages are written already—perhaps I am just about in the middle of the work." Last year he spent seven months in the U.S. and in the fall gave a series of lectures in Italy. He admits, however, that one approaching seventy is glad to get back to the farm.

WHAT'S NEW ABSTRACTS

Pulses Are Quickening

From "The Hot-Wire Anemometer in Supersonic Flow," National Bureau of Standards, Summary Technical Report.

The hot-wire anemometer—a very fine electrically heated wire whose resistance changes with air cooling—has been widely used in wind-tunnel studies of turbulence in the subsonic range.

To extend the range of the hot-wire anemometer into the supersonic region, the National Bureau of Standards recently made a study of the behavior characteristics of this instrument at air speeds up to twice the speed of sound (See "Heat-loss characteristics of hot-wire anemometers at various densities in transonic and supersonic flow," by W. G. Spangenberg, NACA Technical Note).

The hot-wire anemometer's high response to rapid variations in velocity has made it useful in measuring turbulence at low subsonic speeds in terms of magnitude and frequency of velocity fluctuations. At high subsonic and supersonic speeds the frequency range must be extended from about 10,000 to about 100,000 cps. Also, because of compressibility effects and the large amounts of power expended in supersonic wind tunnels, fluctuations of density and temperature occur along with velocity fluctuations. These factors contribute in one way or another to the aerodynamic behavior of a model in a supersonic wind tunnel, and to a degree yet unknown, to the behavior of bodies in flight. The object of the NBS investigation was to determine the response characteristics of the hot-wire anemometer to all of the known variables associated with turbulence at high speeds.

Because of the high frequencies anticipated at supersonic speeds, wires as small as 0.00005 in. in diameter were studied. The wires were made of platinum, tungsten, and platinum-rhodium; their diameters ranged from 0.00005 to 0.0015 in.

The bureau experimented with several types of hot-wire probes in an effort to find a design sufficiently rigid to withstand the stresses and vibrational forces encountered in the transonic speed region and during the passage of the shock wave produced by starting and stopping the tunnel. In the design finally adopted, the heated wire was attached to the ends of two honed sewing needles, 0.018 in. in diam, butt-brazed to electrical leads embedded in hard rubber. To minimize the end-loss correction, the needles were usually spaced for a wire about 3 mm long.

It was found that wire diameter and air density are effectively equivalent variables, but that velocity and Mach number (whose effects could not be separated) influence the heat loss entirely differently. When density and wire diameter were held constant, an increasing Mach number was accompanied by a decreasing sensitivity to velocity change. In fact, this sensitivity actually became negative under certain conditions as the speed of sound was approached in the subsonic region. These Mach number effects were less at supersonic speeds, and tended to disappear as a Mach number of 2 was approached. However, no data were obtained above this speed.

It was found also that the heat loss does not vary directly as the temperature difference between the wire and the air. The heat loss per degree may either increase or decrease with temperature loading, depending upon air density, Mach number, and wire temperature and diameter. Wires inclined to the wind direction showed heat losses dependent upon the component of velocity normal to the wire. They displayed supersonic characteristics in a supersonic stream only when this normal component was supersonic.

Controls for the Atom

From "Nuclear Reactor Control," by J. M. Harrer, Argonne National Laboratory, Lemont, Ill., "Electrical Engineering," March, 1955.

Neutron density is the primary measure of reactor power because a production of about 7.5 x 10^{10} neutrons per sec result in a watt. The three basic conditions which determine neutron density are:

▶ Subcritical where neutron produc-

tion is less than absorption plus leakage of neutrons

- ▶ Critical where neutron production equals absorption plus leakage
- ▶ Supercritical where neutron production exceeds absorption plus leakage

These conditions can exist at any neutron density from a microwatt up to a design power maximum in megawatts. To give continuous instrumentation a suitable neutron-producing source such as a few grams of radium in close proximity to beryllium has been designed into the reactor. This source is so located that, to reach the instruments, the neutrons pass through the reactor core which contains the fissionable material.

The basic method of control does not vary. For subcritical, a constant neutron density in the reactor will be reached, which will increase only if (1) fissionable material is added (to increase neutron production); (2) reflecting material, or alternately moderator material, is added (to reduce neutron leakage); (3) built-in absorber material (such as cadmium or boron) is removed.

To change neutron density, change production, absorption, or leakage.

In the critical condition neutron density will rise at a constant rate depending upon the number of neutrons injected per unit time by the source. If the source is removed, neutron density will remain constant.

The supercritical condition is shown by an exponential rise in neutron density. These conditions in the reactor are designated by the quantity k, which is the number of neutrons produced for each neutron absorbed in fission. For example, subcritically, k is less than 1. Further taking (k-1) obtains the control parameter δk called reactivity that the control engineer uses continuously. The units of this quantity are neutrons per neutron so it is dimensionless.

NEUTRON DETECTORS

Neutron detectors have conducting electrodes, electrically insulated, surrounded by a gas as helium. The electrodes can be coated with a neutron absorber (e.g., boron) which gives off alpha rays to ionize the gas atmosphere when neutrons are captured. Alternately, the chamber can be filled with boron trifluoride gas and can have uncoated plates, giving the same alpha ionization effect right in the

gas. With a potential applied to the electrodes, an electric current will result proportional to the gas ionization. This current is, therefore, proportional to the neutron density at the chamber. If the chamber has been placed strategically, the current is proportional to neutron density in the reactor.

NEUTRON DENSITY CONTROL

Many ingenious ideas have been presented for reactor control, very few of which have been tried, and this is certainly one way that engineers can contribute to practical reactor development. In the end, mechanical rod movement inside the core usually is used.

The kinetics of the rods for good reactor control is different for every reactor type. However, certain general specifications which must be met for all reactors using mechanical rods can easily be drawn up:

- ► The rods must be able to increase or decrease reactivity at rates of about 10^{-5} δk per second. A typical mechanical control speed corresponding to this δk-per-sec figure would be about 0.1 in. per sec. Variable speeds to increase this rate five to ten times are convenient.
- ► The rods must move rapidly with at least a net acceleration of gravity to reduce reactivity and stop the reaction in emergencies. Because of friction and the possibility of sticking, some kind of spring usually is provided to make this "scram" very certain.
- ► Rods should remain stationary at any position to which they are moved by the mechanism. They should not drift or vibrate to any extent under the effect of mechanical forces acting on them due to the circulation of coolant in the reactor.
- ► Accurate measurement of position should be possible at a remote point convenient for the operator.

High-gain Strategies

From "Gain Measurements on Computing Amplifiers," by A. B. Johnson, Saunders Roe, Ltd., "Electronic Engineering," March, 1955, London

The internal gain of a computing amplifier determines its computing accuracy, output impedance and input impedance. It also affects the decay time-constant of a "holding" integrator. It is easy to calculate the gain,

ABSTRACTS

but since large errors are likely, measurement is better.

It's not easy to measure this gain since most amplifiers cannot be operated without negative feedback. An amplifier with an internal gain of 10^5 and a short-term drift of 1 millivolt might produce an output noise level of 100 volts and overload the output stage before any test signal could be applied.

Methods of measurement can be divided roughly into two classes: direct, where the amplifier is effectively working without feedback; indirect, where the drift output is small because of negative feedback and the gain is deduced from some property of the experimental arrangement.

The best method depends upon the gain and drift, and if these are both low enough to permit the amplifier to work without feedback, measurement is quite simple.

Direct methods of gain measurement include:

► Introduction of ac couplings

Drift noise is reduced by temporarily replacing one or more direct couplings within the amplifier with ac couplings

► Feedback at dc only

A low-pass filter in the feedback path provides full feedback at dc, and full gain at some high measurement frequency

► Grid voltage measurement

Comparison of grid voltage with input voltage will give gain, if grid is fed through a series resistor equal to feedback resistor.

Indirect methods include:

► Computation error

Ratio of output to input voltage is compared with ratio of series and feedback resistors. Good only for fairly low gains.

► Grid terminal impedance

By shunting the grid with lower and lower resistors until the output is reduced to half, the gain becomes equal to the ratio of the feedback resistor to the grid shunt resistor.

► Integrator decay time constant

Taking account of leakage in the capacitor, the decay time constant of an integrator is directly a function of amplifier gain.

► Output impedance

Amplifier output impedance is indirectly proportional to gain.

Increasing the output impedance artificially by adding external resistance allows accurate measurement of gain.

APRIL

American Society of Mechanical Engineers, Instruments and Regulators Conference, Ann Arbor, Mich. Apr. 25-26

Southern Methodist University, Department of Electrical Engineering, Third Annual Southwest Conference on Feedback Control Systems, Southern Methodist University, Dallas, Texas. Apr. 28-29

MAY

Instrument Society of America, First National Flight Test Instrumentation Symposium, Allis Hotel, Wichita, Kans. May 3-5

Institute of Radio Engineers, National Conference on Aeronautical Electronics, Biltmore Hotel, Dayton, Ohio. May 9-11

Engineering Symposium – "Automation-Engineering for Tomorrow," Michigan State College, East Lansing, Mich. May 12-14

American Institute of Electrical Engineers, National Telemetering Conference, Chicago. May 18-20

JUNE

Human Engineering Institute, Course in Human Engineering, Dunlap and Associates, Inc., Stamford, Conn. June 6-10

Society of Automotive Engineers, Golden Anniversary Summer Meeting. Atlantic City. June 12-17

American Society of Mechanical Engineers, Combustion Conference, IRD Session on Control of Industrial Furnaces, Massachusetts Institute of Technology, Cambridge, Mass. June 15-17

American Society of Mechanical Engineers, Diamond Jubilee Semi-Annual Meeting, IRD Session on Thermodynamics, Hotel Statler, Boston, Mass. June 19-23

American Institute of Electrical Engineers, Summer General Meeting, New Ocean House, Swampscott, Mass. June 27-July 1

AUGUST

Stanford Research Institute and National Industrial Conference Board, Symposium on Electronics and Automatic Production, Civic Auditorium, San Francisco, Calif. Aug. 22-23

Western Electronics Show and Convention, San Francisco Civic Auditorium, San Francisco. Aug. 24-26

The Classified Advertising Section of **CONTROL** ENGINEERING

EMPLOYMENT: BUSINESS: **"OPPORTUNITIES"** :EQUIPMENT :USED OR RESALE

—RATES—

UNDISPLAYED

$1.50 per line, minimum 3 lines. To figure advance payment count 5 average words as a line

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Advertising inch measures 7/8" vertically on one col., 3 col.—10"—to a page.

EMPLOYMENT ADVERTISING

New Employment Opportunities Section for Displayed ads starting July issue. For further details see announcement ad in this section.

New Ads Received by May 4th at the New York office, 330 W. 42nd St., New York 36, N. Y., will appear in the June issue subject to limitations of space available.

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To coordinate and supervise a group of engineers and mathematicians in systems analysis and design.

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Evaluation of servo control and guidance systems and components of a system Analysis of systems and applications.

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Design of automatic machine tools, machine tool hydraulic servos, and digitally controlled tools.

CONTROLS ENGINEERS
Analyse and synthesize control system and design, develop and package such systems.

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Development of special purpose digital and analog computers for process and business applications.

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Develop mechanical and hydraulic components for servo controls. Systems engineering and dynamic analysis of numerically controlled machine tools.

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SERVOMECHANISMS AND CONTROL SYSTEM ANALYSIS
ELECTRONIC EQUIPMENT PACKAGING
INSTRUMENT DESIGN
MISSILE SYSTEMS DEVELOPMENT
FLIGHT TESTING

Please Send your resume to
Professional Staff Appointments
APPLIED PHYSICS LABORATORY
THE JOHNS HOPKINS UNIVERSITY
8621 Georgia Avenue
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M.S.or Ph.D

Senior engineers and physicists with excellent grounding in fundamentals of both analytical and laboratory research and development are needed for new activities in computers, automatic controls, and electromechanical design.

Men with versatility and leadership ability will be offered the opportunity to develop research programs along the lines of their own experience and interest within the wide scope of activities possible in an independent organization.

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S. J. Keane, Physics Department
Southwest Research Institute
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1. New England
2. New York
3. Baltimore-Philadelphia
4. Cleveland
5. Chicago
6. Seattle
7. Los Angeles
8. Dallas
9. Detroit
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In complete confidence give technical qualifications, background, lines carried to:

RW-6089, Control Engineering
330 West 42nd St. New York 36, N. Y.

ATTENTION . . .

EMPLOYMENT ADVERTISERS

Effective with the July issue, a new section will start in Control Engineering. We will head this section: EMPLOYMENT OPPORTUNITIES. All Displayed Employment Opportunity advertising will be placed in this new section, with the exception of those advertisers who contract for run-of-book position. Advertising in the EMPLOYMENT OPPORTUNITIES section will be billed at the new rates which go into effect with the July issue on all Displayed Employment advertising. Contract rates furnished on request. Ads are subject to Agency Commission.

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PHYSICISTS
SALES ENGINEERS

Burroughs
Research Center, Paoli, Pa.
Invites You

To Inspect Its Openings on Both Commercial & Sponsored Projects

Enjoy These Advantages!

In addition to paid vacations, liberal pension plans and numerous other valuable health and hospitalization benefits for you and your family, we provide cooperative educational aid at one of the many technical schools in the Philadelphia area for qualified applicants who find our center an ideal work-shop in which to secure the desired recognition in their chosen fields.

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If you want the BEST for yourself and your family, consider NOW your qualifications for the openings listed on the right and —

Write **L. E. DICK**, *Personnel Manager*
BURROUGHS RESEARCH CENTER
Paoli, Pa.

Located on
PHILADELPHIA'S "MAIN LINE"

If you possess an educational and/or work background in Communications, Data Handling, Electronic, or Electro-Mechanical Business Machines...including such specifics as High Speed Mechanisms, Paper Handling Devices, Magnetic-Tape Transport Mechanisms, Magnetic-Drum or Tape Applications, Radar, Telemetering, Guided Missiles, Process Control Instrumentation, Digital and Analog Computers, Transistor and Magnetic Circuit Design and Analysis, Magnetic Amplifiers, Servo Mechanisms, and Electronic Packaging Design . . .

CONSIDER THESE OPENINGS AS

- **ELECTRICAL ENGINEERS; Junior & Senior**
- **MECHANICAL ENGINEERS; Junior & Senior**
- **LOGICAL DESIGNERS** • **PHYSICISTS**
- **PROJECT ENGINEERS**

- **SALES ENGINEERS** to sell E-101 electronic desk computers in all sections of the country. Sales & Technical experience in allied lines desirable.

Your inquiry will have special value . . .

if you mention this magazine, when writing advertisers. Naturally, the publisher will appreciate it . . . but, more important, it will identify you as one of the men the advertiser wants to reach with this message . . . and help to make possible enlarged future service to you as a reader.

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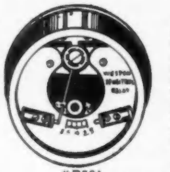
PRODUCTION QUANTITIES

SEND FOR LATEST CIRCULARS
LISTING NEW ITEMS—NEW LOW PRICES

WESTON TYPE 705 SENSITROL


#R561

Operation is as follows: The stationary contact is a small powerful permanent magnet and movable contact is iron "rider" mounted on pointer which travels over relay scale. Operating torque moves pointer into magnetic field of stationary contact. This contact then draws movable contact and holds it firmly. Contacts remain closed until reset. Will operate directly from a photocell or a group of thermocouples. Net weight 14 oz.

Double contact with Solenoid Reset; Sensitivity 7.5 Microamps; Reset coil 6-24 VDC or 24 VAC; Makes contact on increasing or decreasing values; Contacts; "Twintacts", Capacity 100 ma at 110 volts; Nickel plated. Brass cover; Weston Model 705 Type 6 #R560 ....**18.75; 10 for 170.00**

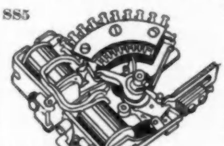
Same as #R560 but with glass face; Weston Model 705 Type 6 #R51.**19.75; 10 for 180.00**

Single contact (Normally Open), Solenoid Reset; Sensitivity; 10 Microamperes; Reset coil; 6-24 V DC or 24 V AC; Contact: "Twintact", capacity 100 ma at 110 volts; Glass Face; Weston Model 705 Type 4 #R523.**17.75**
10 for 160.00

Same as #R523 with Brass Cover Weston Model 705 Type 4 #R523N............**16.75**
10 for 150.00

STEPPING SWITCHES

SS5


Step & Reset

Mfg by Western Electric, Automatic Electric Sales
Minor Switch
10 steps and off
Contacts: Gold plated brass;
BridgingWiper;
Operating Voltage 6.0 to 12.0 V. DC
Net Wt. 1 lb.

	Each	Lots of 10
#R960; Single Level; 6 to 12 VDC.	**10.95**	**9.00**
#R975; Single Level; 24 to 36 VDC.	**11.95**	**10.00**
#R976; Single Level; 48 to 60 VDC.	**12.95**	**11.00**
#R977; Two Level; 6 to 12 VDC.	**12.95**	**11.00**
#R978; Two Level; 24 to 36 VDC.	**13.95**	**12.00**
#R979; Two Level; 48 to 60 VDC.	**14.95**	**13.00**

SS6 Mfg. by Western Electric Co.; 22 step; 5 levels; Bridging Wipers; Contacts: Gold plated brass. Interrupter Switch: 1 Break-Make; Net Weight: 2 lb. 2 oz.

"Homing" Type; Double-Ended Wipers; Step in One Direction

#R926; 6 to 12 VDC............	**14.75**	**12.00**
#R980; 24 to 36 VDC............	**15.75**	**13.00**
#R981; 48 to 60 VDC............	**16.75**	**14.00**

SS7 Mfg. by Western Electric Co.; 44 step; 2 Levels; Bridging Wipers; Contacts: Gold plated brass; Interrupter Switch; 1 Break-Make; Net Weight 1 lb. 14 oz.

"Homing" Type; Double-Ended Wipers; Step in One Direction

#R927; 6 to 12 VDC............	**14.75**	**12.00**
#R982; 24 to 36 VDC............	**15.75**	**13.00**
#R983; 48 to 60 VDC............	**16.75**	**14.00**

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Universal general corp.

problem: gravity

Interested in it? So are we. For part of the advanced development program at Martin includes an overall search into the basic laws of the universe — probing the unknown in any field that relates to airborne systems.

Gravity is a personal problem to many creative engineers today: men who are lost in large engineering organizations; anchored to non-creative and futureless jobs. Ceiling Zero, Altitude Zero.

If you are one of those, you'd do well to look into the Martin story. For exciting new long-range developments have created many exceptional opportunities on projects of the highest priority and importance.

Contact J. M. Hollyday, Dept. C-5, The Glenn L. Martin Company, Baltimore 3, Maryland.

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